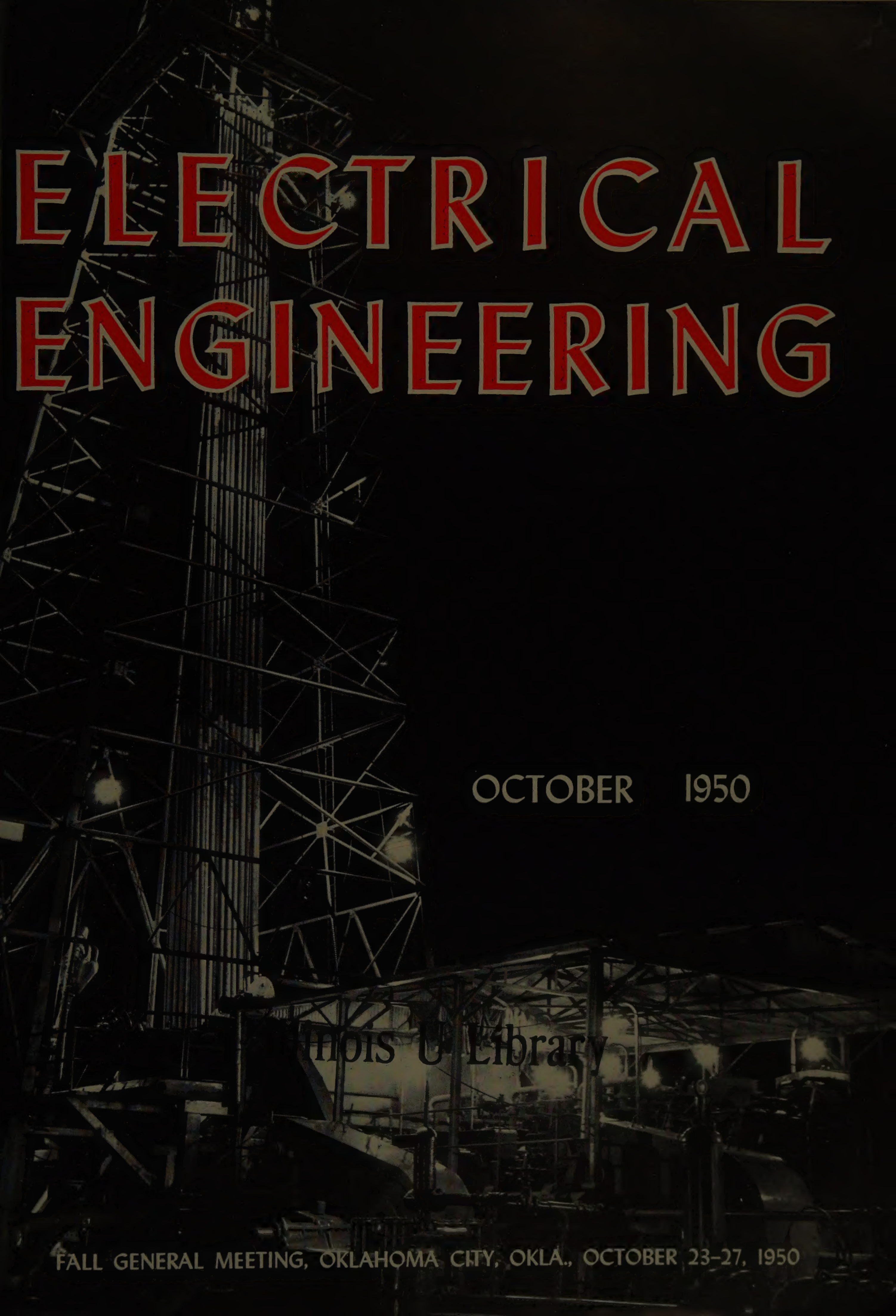
ELECTRICAL ENGINEERING



OCTOBER 1950

FALL GENERAL MEETING, OKLAHOMA CITY, OKLA., OCTOBER 23-27, 1950

ELECTRICAL ENGINEERING

Registered United States Patent Office

OCTOBER 1950

The Cover: The drill stem used in drilling this well has just been removed from the hole so that the worn bit can be replaced. The Fall General Meeting will feature two sessions on Oil Industry Applications and an inspection trip of the Oklahoma City oil fields (program on pages 928–29).

Standard Oil Company of New Jersey photo

Are Institute Elections Democratic? ... T. G. LeClair ... 855
Call for Nominations of Officers for 1951 Election ... 857
The Rising Tide of Business and Industry on the Pacific Slope ... Alden G. Roach ... 858
Multistation Control, Telemetering, and Communication on Single-Frequency Carrier ... W. A. Derr, T. C. Wren, J. V. Kresser ... 862
Handling Power System Problems on an A-C Network Calculator ... P. O. Bobo ... 867
Structure and Polarization of Atoms and Molecules ... J. C. Slater ... 872
Design of Log-Scale D-C Meters ... Allen Stimson, C. F. Taylor ... 877
Survey of Bushing-Type Current Transformers for Metering Purposes ... G. Camilli ... 882
Transmission Substation Design—A Departure from the Usual ... E. V. Sayles ... 886
A Distributed Power Amplifier ... A. P. Copson ... 893
Solderless Commutator Joints for Railway Traction Armatures ... J. R. Reed ... 901
Desert Measurements of Corona Loss ... W. S. Peterson, B. Cozzens, J. S. Carroll ... 907
Performance of Electric Locomotives ... A. H. Candee ... 913
108 Are Missing ... E. C. Hunt ... 919
Transverse Flux Induction Heating ... R. M. Baker ... 922

TECHNICAL-PAPER DIGESTS

High-Interrupting-Capacity Low-Voltage Power Fuses ... C. L. Schuck ... 861
Expansion of the Southern California Edison System A ... A. A. Kroneberg ... 870
Ignitron Converters for High-Energy Accelerators ... J. L. Boyer, C. R. Marcum ... 871
Amplidyne-Controlled Log Carriage Drive ... W. D. Vincent ... 876
Selection and Application of Power Transformers ... H. P. Seelye ... 885
Locomotive Wheel-Slip and Wheel-Lock Protection ... R. M. Smith ... 891
Simple New Resistance-Type A-C Load-Flow Board ... Waldo E. Enns ... 892
Main Power Transformers for Generating Stations ... N. E. Dillow, J. W. Butler ... 899
Economic Aspects of Large Power Transformers ... C. M. Short, W. G. Hart ... 900
Underground Hydroelectric Power Plants ... Paul E. Gisiger ... 905
Crossbar Tandem System ... R. E. Collis ... 906

Miscellaneous Short Items: New Speech Analysis Equipment, 875; Electrical Essays, 924; Draft Status of Students Clarified, 925

Institute Activities ... 926
AIEE Personalities, 933; Obituary, 936; Membership, 936

AIEE Technical Subcommittee Personnel ... 937

Of Current Interest ... 945
New Books, 948; Pamphlets, 950

Industrial Notes ... 16A
New Products, 16A; Trade Literature, 50A

Index to Advertisers ... 74A

VOL. 69 NO. 10

Statements and opinions given in articles appearing in *ELECTRICAL ENGINEERING* are expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on controversial matters. Published monthly by the

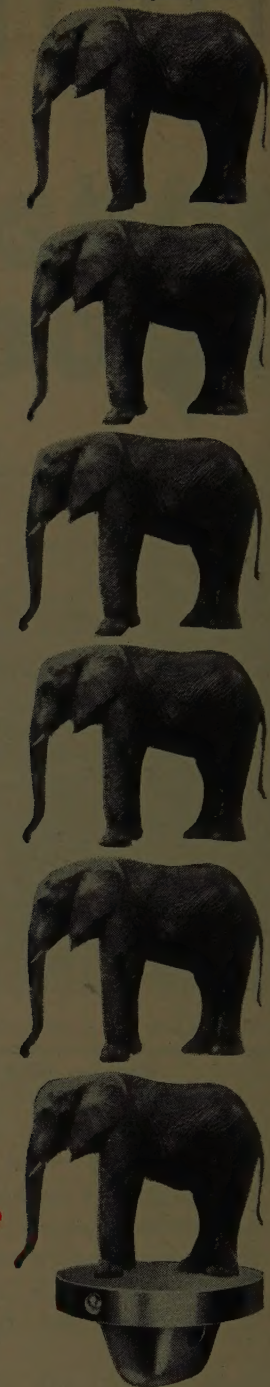
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

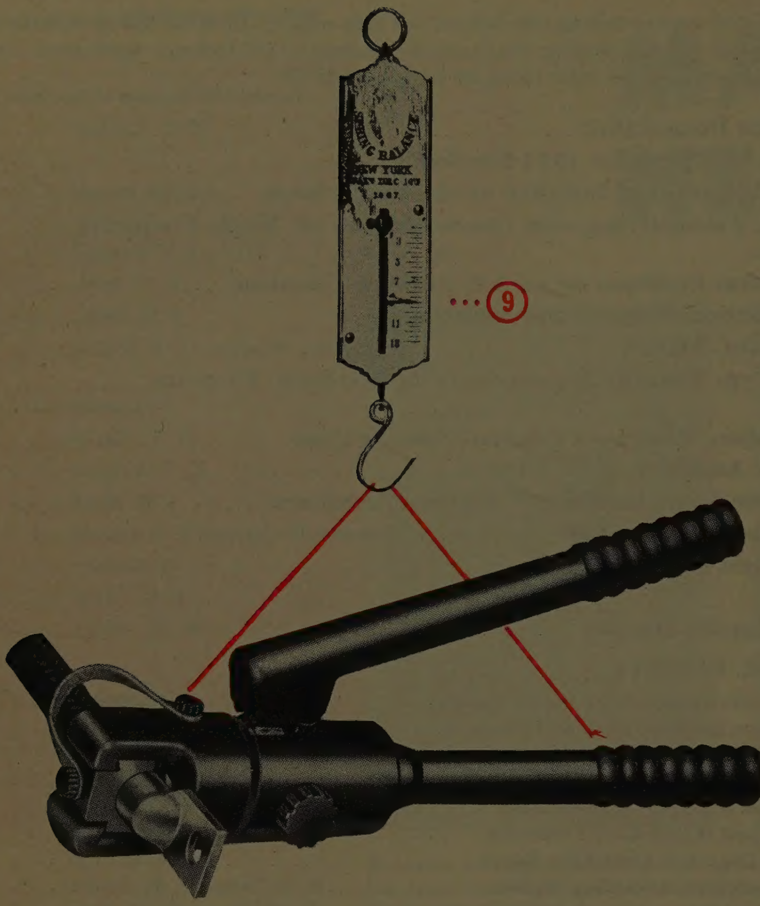
Founded 1884

Headquarters
33 West 39th Street
New York 18, N. Y.

Editorial Offices
500 Fifth Avenue
New York 18, N. Y.

SKEPTICS:
Young elephants weigh about 3,000 pounds each

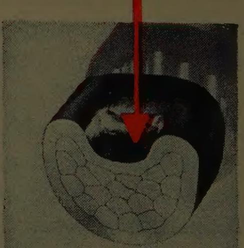


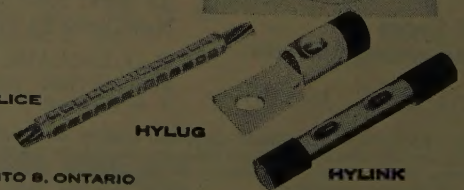


9 pound Hypress exerts 9 ton pressure

You'd naturally expect this superior indent tool from the originators of Hydent indent connectors—Burndy! 19 inches long, light weight, handy to operate, this fully insulated hydraulic Hypress (Y34A) delivers up to 18,000 pounds of pressure with automatically controlled depth of indentation. Assures strong, efficient electrical connections every time.

BURNDY
ELECTRICAL CONNECTORS





BURNDY, N. Y. 54 N. Y. • WESTERN BRANCH: VERNON 58, CALIF. • BURNDY CANADA LTD., TORONTO 8, ONTARIO

HIGHLIGHTS . . . .

Are Institute Elections Democratic? T. G. LeClair, AIEE President, gives his opinion on this question and points out some of the factors involved in Institute election procedure (*pages 855–56*). He summarizes the elective process and calls for nominations of officers for the coming year (*page 857*). Members are requested to fill in a coupon with answers to two important questions and give any suggestions they may have regarding Institute elections (*page 856*).

AIEE Technical Subcommittees. Over 200 technical subcommittees of the Institute and their personnel are listed in this issue (*pages 937–44*). This is in completion of the list in the September issue (*EE, Sept '50, pp 833–38*), which presented Institute officers and the personnel of the main general and technical committees.

Fall General Meeting. The 1950 Fall General Meeting of the Institute will be held in Oklahoma City October 23–27. An interesting technical program has been arranged. Inspection trips include one to the oil fields, one to the Belle Isle Generating Station and Mustang Station, a trip to Tinker Air Force Base, and a tour through a television station (*pages 926–30*).

Single-Frequency Carrier. Multistation supervisory control, selective telemetering, and communication are accomplished by the Sierra Pacific Power Company on a single frequency carrier channel. This system is not only economical financially, but it is frugal with difficult-to-obtain frequencies as well (*pages 862–67*).

A-C Network Calculator. A-c calculating boards are being used more and more in the solution of the problems of power systems. The boards have been improved and new techniques of operating them developed so that the problems can be solved more efficiently (*pages 867–69*).

News Index

Institute Activities 926

Fall General Meeting 926
Future AIEE Meetings 926
Fall Meeting Program 928
IRE/AIEE Nucleonics Conference 930
AIEE Board of Directors Meet 931
Committee Notes 933
AIEE Personalities 933
Obituary 936
Membership 936

Of Current Interest 945

Fulbright Opportunities 945
Labor-Management Co-operation for Safety . . . 945
Future Meetings of Other Societies 945
New Books 948
Pamphlets 950

Structure and Polarization of Matter. Dipoles can be studied by means of such simple mechanical models as a linear oscillator, a perfectly conducting sphere, and a freely moving dipole of fixed dipole moment. These studies lead to the concept of dielectrics from a molecular point of view (*pages 872–75*).

Log-Scale D-C Meters. The general principles applying to the design of log-scale d-c indicating instruments are described in this issue, and their use is illustrated by reference to a new exposure meter. The mathematical background of the system is developed, and the design of the magnetic system shown (*pages 877–82*).

Bushing-Type Current Transformers The exceptional simplicity, convenience reliability, adaptability to high voltages, and economy of the bushing-type current transformer has made it a widely used device. However, it has not been adaptable to small line currents. This article describes the attempts at improving its accuracy to make it suitable for metering at small line currents (*pages 882–84*).

Transmission Substation Design. A number of innovations have been used in recent installations of substations for the Consumers Power Company of Jackson, Mich. Prefabricated steel sections have been made for use in the erection of all structures, design of switchboards has been standardized, unit control houses are used, and overhead conduit is being used in place of the usual underground ducts and control cables (*pages 886–90*).

A Distributed Power Amplifier. The theory of distributed amplifiers is described this month, and the results of tests made on a distributed power amplifier and a distributed voltage amplifier are presented. These amplifiers use artificial transmission lines to avoid the problem common to most video amplifiers of the tube load impedance decreasing at higher frequencies; they give a frequency response within a few decibels from a few cycles to hundreds of megacycles (*pages 893–98*).

Solderless Commutator Joints. With the development of better heat-resistant insulations, the soldered joints in motors of electric traction equipment have been subjected to severe operating conditions. Joints which eliminate entirely the use of solder have been developed and are described this month (*pages 901–04*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions*.

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Jul '49, p 47A	South West District Summer General
Nov '49, p 51A	Pacific General Fall General
Feb '50, p 46A	Winter General
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General (1950)

Desert Measurement of Corona Loss. Loss values found to exist under desert atmospheric conditions show that corona losses occur at lower voltages on the desert than under normal climatic conditions. A description of the methods used in measuring these losses and the data obtained are given this month (*pages 907–12*).

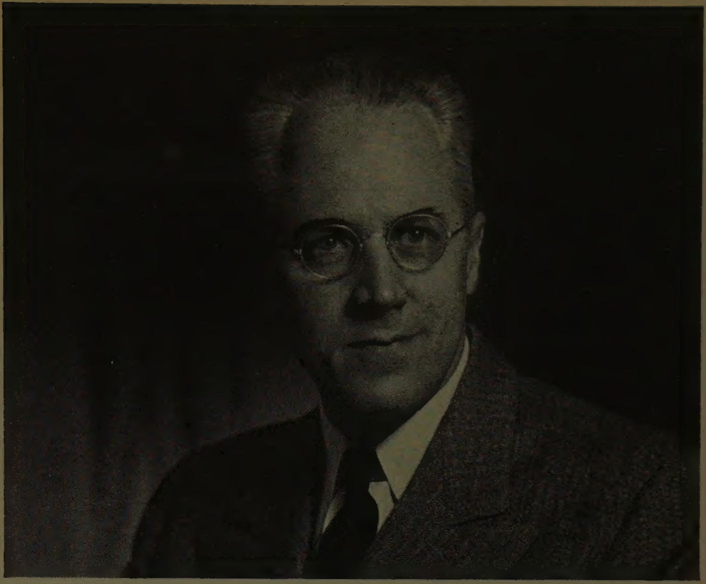
Performance of Electric Locomotives. A study of the characteristics of three types of locomotives, reciprocating steam, trolley electric, and self-propelled electric, such as diesel, shows that the electric types have characteristics which may be used to better advantage under almost all conditions met in railroad operation (*pages 913–18*).

108 Are Missing. Accidents which cost the lives of 108 workmen of a large public utility are studied by E. C. Hunt, safety engineer of the Pacific Gas and Electric Company. The study shows that contributory neglect and human failure are the two factors which lead to most accidents; they must be taken into account in order to reduce accidents (*pages 919–21*).

Transverse Flux Induction Heating. This method was devised for nonferrous strip materials because longitudinal flux induction heating was impractical. The use of certain frequencies is discussed and terminal power and conversion efficiency are described (*pages 922–24*).

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices 500 Fifth Avenue, New York 18, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. October 1950, Vol. 69, No. 10. Number of copies of this issue 52,100

Are Institute Elections Democratic?



T. G LECLAIR
PRESIDENT AIEE

In answer to questions which have come up recently regarding the Institute's election procedure, President LeClair reviews the present process and analyzes some of the suggestions which have been made to change it. Comments by the membership will be welcomed; a convenient form, which may be detached and mailed, will be found on page 856.

SUCH a fast-growing organization as the Institute must always be alert to changes which warrant a change in its method of operation. Among such possibilities is the process of election. Within the past few months perhaps a dozen letters have been written either to the President or to the Secretary inquiring as to the origin of the present election procedure or questioning its desirability. If a dozen persons take the trouble to sit down and write a letter, I assume that many times that number have a real interest in an answer to the question, even though they may not have taken the trouble to put their thoughts in writing. If the answers to this article indicate a desire for a change in the present practices, suitable committees will see to it that Constitutional amendments are submitted to the membership.

Any analysis of the Institute's election procedure requires a little thought on the nature of the Institute itself. The Institute is a professional group which serves as a forum for the interchange of ideas among its members and as a source of new knowledge and of improved standards to industry; it is also a spokesman for its members. The Institute's officers all serve without pay, giving of their time generously and willingly. Candidates for political office seek office intently by extolling their own virtues to the public in hopes that they may obtain an office from which there will be monetary as well as indirect gains. Officers of a corporation are selected by a board of directors in a strictly autocratic manner solely with the understanding that they will carry out the obligations of their office in such a way that the corporation will succeed and be justified in paying the officers their salaries. Officers of the Institute fit into neither such category even though the Institute with its 37,000 members and assets over $1,000,000 has become a rather large business organization.

T. G. LeClair is Chief Electrical Engineer, Commonwealth Edison Company, Chicago, Ill.

THE PRESENT PROCESS

THE INSTITUTE, covering an international area and with membership in various branches of the electrical industry, must have its officers over a period of time representative of the various branches of industry and of the educational sources from which engineers are obtained, as well as from the various sections of the country, so that officers may be fully cognizant of the needs of the Institute in conducting its business affairs. Also, a certain degree of continuity should be maintained in the offices of the Institute so that policies may be carried on continuously for successful operation. The present method of selecting officers was intended to meet these needs, and it was believed to be meeting them satisfactorily, but it may be that an improvement can be obtained.

A suggestion has been made that the Nominating Committee select two candidates for each office in order that the membership as a whole may have a choice between these two candidates in the annual ballot. There would undoubtedly be an advantage in having two names on which to vote, provided that the individual member knew either of the candidates and could vote intelligently on which one was the best qualified to fill the office. This would certainly carry out the ideal of a democratic form of organization. However, bearing in mind that an office in the Institute is considered an honor and an opportunity to be of service, many outstanding men might refuse to permit their name to be put on the ballot and made the subject of political compaigning. The office might cease to be an honor if candidates openly sought to fill the office.

Another suggestion which has been made is to send out

a primary ballot to every member of the Institute asking him to suggest names for each of the offices to be filled in the current year. This might be effective if more than ten per cent of the membership would send in primary ballots, and also if the primary ballots sent in would result in any material fraction of the ballots being cast for a single candidate for any such office. Apparently, those who wrote the present Constitution and Bylaws were concerned for fear that such a primary ballot would result in more confusion than accurate selection. If names are to be suggested in advance for this primary ballot, it still requires that some nominating group go through the process of selecting several names rather than just one as at present.

A DEMOCRATIC METHOD

WHAT is there about the present election procedure which has caused some members to question its democracy? On the following page is the annual statement summarizing the Institute's election procedure and asking for suggestions to be used in selecting officers for the year 1951–52. I commend this to your attention.

You will note that several safeguards have been included to insure a reasonably democratic selection of officers. First, the Nominating Committee must be selected with at least one member from each of the ten Districts, which insures that every area have an opportunity to have some voice. Second, each year a request is printed in *Electrical Engineering* that every individual or group in the Institute send in suggestions to the Nominating Committee. Third, and not the least important, is the statement which is printed twice each year that any 25 members, which constitutes less than one-tenth of one per cent of the Institute membership, may file a petition to put an additional candidate on the ballot for any office if they are not completely satisfied with the selections made by the Nominating Committee.

Could it be that the present questions arise from the fact that we seldom read the magazine, but that we do read our letters? How many Institute members know that they are asked to submit suggestions for every office before the Nominating Committee meets? How many members know that additional candidates may be put on the ticket by petition?

Should we change the election procedures? Instead of sending out a ballot near the end of the administrative year with only a single list of names, should we send out a direct-mail request for suggestions at the beginning of the year? Should we then assume that the selections of the Nominating Committee be declared elected unless a petition is filed within a suitable time after the names of candidates are announced?

COMMENTS REQUESTED

FOR YOUR convenience two questions and a request for comments are printed at the bottom of this page. The Committee on Planning and Co-ordination has agreed to study the answers to these questions and report at a later date on the wishes of the membership so received. If the report of this committee indicates that an improvement can be made in the election procedure, you may be assured that appropriate changes in the Constitution and Bylaws will be submitted for letter-ballot.

Last, but not least, when the Nominating Committee has selected candidates for offices next year, please indicate your confidence in the present and future management of the Institute by marking the ballot.

Detach and Mail

To the Secretary

Committee on Planning and Co-ordination, AIEE
33 West 39th Street, New York 18, N. Y.

1. Would you recommend that a direct-mail request for nominations be sent to each member at a cost of approximately 15 cents per member, with the understanding that a corresponding service of some other type be omitted?

Yes ☐ No ☐

2. Would you recommend that the primary ballot or request for suggestions be substituted for the present election ballot with the understanding that the action of the Nominating Committee shall be considered final in the absence of a ticket by petition?

Yes ☐ No ☐

3. If you have any other suggestions please list them here. . . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

NAME. . . . .
ADDRESS. . . . .

Call for Nominations of Officers for 1951 Election

THE CONSTITUTION and Bylaws of the Institute, in establishing the procedure to be followed in choosing our officers, also makes adequate provision for any *individual* member or group of members to make known their preferences. To the many busy members who do not familiarize themselves with these provisions, the following digest of the applicable sections will be of interest.

Official nominations for Vice-Presidents are made by the respective District Executive Committees in which a vacancy will occur. Hence, any member who has an opinion on vice-presidential nomination should communicate with his own Section Chairman or Secretary, both of whom are members of the District Executive Committee. In September of each year the Institute Secretary notifies District Executive Committees, in those Districts which will have a vacancy, that it is their duty to make nominations and advise him not later than December 15.

Official nominations for President, Treasurer, and Directors of the Institute are made by the Nominating Committee, which is composed of 15 members, one selected by each of the ten District Executive Committees and five selected by the Board of Directors from its membership. The Secretary of the Institute, who also serves as Secretary of the Nominating Committee, calls a meeting of the Nominating Committee not later than January 31. Individual members or groups of members who have preferences as to nominations should make them known by writing to the Secretary prior to this January meeting. The committee then considers all suggestions and recommendations received and makes up a ticket of nominees for the offices to be filled at the next election. In case any Districts have failed to make nominations for Vice-Presidents, the Nominating Committee will make such nominations for the Districts concerned. All of the nominations are published in the March issue of *Electrical Engineering* so that all members may be aware of the nominations within the first week in March.

In addition to the privilege of making suggestions to the Nominating Committee, any group of 25 or more members who are not satisfied with their action may make additional nominations by petition to the Secretary of the Nominating Committee. Such petitions must be received by the Secretary of the Nominating Committee not later than March 25 in order to be placed on the ballot.

This is essentially the procedure set up by the Constitution, Article VI, Sections 28 to 31, and Sections 21 and 22 of the Bylaws. The Constitution also provides that Fellows only are eligible for the office of President, and Members and Fellows only for the other elective offices. Although the procedure may seem involved when read from the Constitution and Bylaws, it is really a simple and democratic system of choosing officers.

Since each District has a representative on the Nominating Committee, the representation is well distributed geographically. In addition to the knowledge which these representatives have of the membership, the five members of the Board of Directors on the committee are well acquainted with the Institute's activities and usually would be somewhat aware of the qualifications of members who might be considered for nomination. Besides their own knowledge, they have the suggestions and recommendations made by the membership at large. With this background, the Nominating Committee is in a position to choose qualified officers and does not ordinarily name more than one person for each office.

Although this system leads to the nomination of well-qualified members, it still leaves any group of 25 or more members free to nominate other candidates for any office. This privilege has not been exercised for more than 25 years, which would indicate that the Nominating Committees have made careful and satisfactory selections from the suggestions they have received.

However, the first duty of each member or group who may desire that any particular candidate be considered for office is to inform the Nominating Committee. Have you such a recommendation? **If, so, whom do you recommend for what Institute office for the year 1951–52 and for what reason?** Send your recommendations to the Secretary, Nominating Committee, AIEE, 33 West 39th Street, New York 18, N. Y.

The Rising Tide of Business and Industry on the Pacific Slope

ALDEN G. ROACH

In this address, the President of the Columbia Steel Company, speaking both as a citizen of the West and as a member of the iron and steel industry, examines the phenomenal industrial development of the West during the recent war and postwar periods and evaluates its prospects for the future.

TODAY, more than ever before, business and industry are following the trails blazed by the Daniel Boones and Davey Crocketts of the laboratories. New opportunities are constantly appearing at the frontiers of technological progress. Many of the problems which yesterday imposed limitations on the practical operations of business and industry today have been solved. The chemical formulas and blueprints are being translated into jobs, markets, profits—into well-being for everybody.

The contributions of electrical engineering are important alike to the steel industry and to the industries that consume steel. Electric power, and electric controls and measuring devices, have contributed tremendously to improving efficiency and quality in the industry. Furthermore, these developments have created new demands for iron and steel where no demand existed before. In years to come the West will need such new markets for the products of its open hearths and steel mills. Western industry has skyrocketed in the war and postwar periods. Extraordinary progress has been made, but still more industry will be needed.

During the past ten years, the western iron and steel industry has expanded production and jobs at a more rapid rate than either western population or industry has expanded as a whole. Because of its recent growth this region seems destined to become one of the nation's great manufacturing areas. Even before the war there was a steady, long-term trend upward in population, income, employment, and industrial development, and the trend was accelerated during the war.

At the end of the war the West was steeled for a blow that did not come. Even the United States Employment Service predicted as follows: "Unemployment is expected to increase significantly on the Pacific Coast." The Chamber of Commerce of a large Coast city announced, "We are prepared for the postwar shock." Just after V-J Day some of these predictions seemed justified. Shipbuilding employment in California collapsed from a wartime peak of 274,000 to 8,000. Aircraft employment nose-dived from 237,000 to 55,000.

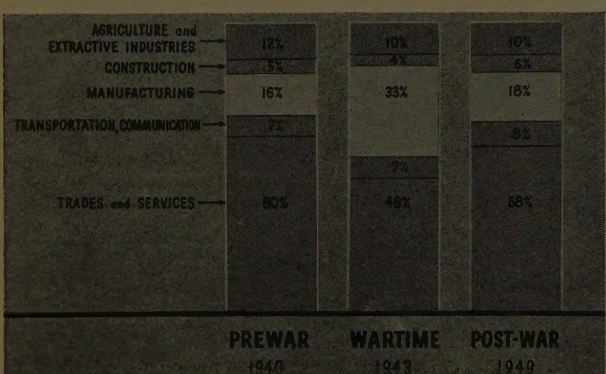


Figure 1. Pattern of employment in California; 1940, 1934, and 1949

But then things started to happen that ruined all the pessimistic prophecies. New people kept arriving. Some of the migrants, who had left the Coast right after the war, returned. Industry converted to peacetime production. Existing plants expanded and new plants were built. Eastern firms established branch operations to feed an expanding western market. Trades and services, starved for help during the war, began to rebuild their forces. Thus was absorbed the increased work force available in the area.

The West has made great strides forward since V-J Day, but the development has been uneven. Some lines of industry have advanced more rapidly than others.

DEGREE AND CHARACTER OF WESTERN GROWTH

A COMPARISON of the growth of the western states and the nation as a whole between 1940 and 1949 indicates that the West has seen one of the greatest human migrations in history. In that period the population of the seven western states grew from 11,500,000 to 17,200,000, an increase of 49 per cent, while the nation as a whole gained only 13 per cent. A comparison of total employment between California and the nation shows that employment in California in that period rose 54 per cent, while the nation's employment rose only 22 per cent.

Figure 1 indicates a very curious aspect of the shifting pattern of employment in California. In particular, a comparison of the trends in manufacturing and in trades and services shows that manufacturing employment was only 16 per cent of the total in 1940, whereas trades and services accounted for 60 per cent. At that time Californians were engaged, to a surprising extent, in "taking in each others' washing."

By 1943, with production for war at its height and trades and services curtailed in activity and personnel, manufac-

Essentially full text of an address presented during the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950.

Alden G. Roach is President, Columbia Steel Company (a United States Steel Corporation subsidiary), San Francisco, Calif.

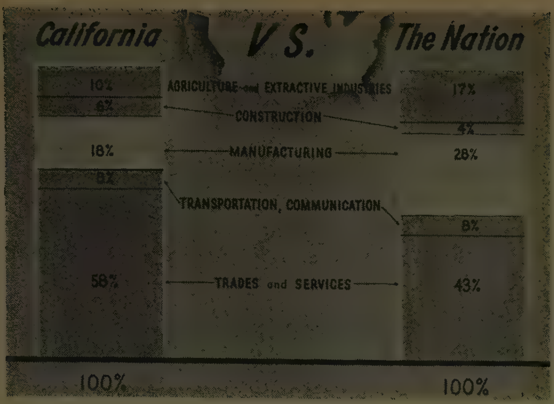


Figure 2. Pattern of employment, United States versus California, in 1949

turing had jumped to 33 per cent of total employment in the state, while trades and services had dropped to 46 per cent. By 1949, however, the old pattern had reasserted itself. Manufacturing jobs were down again to 18 per cent of the total, and trades and services were back up again with 58 per cent. Of course, these percentages apply against a far larger total than do the prewar percentages. Manufacturing employment in 1949, for instance, was 727,000 against 414,000 prewar. However, the similarity of pattern as shown by the percentage figures indicates that the basic nature of western economy has changed but little.

The trades and services category represented in Figure 1 includes all retail and wholesale establishments, laundries, hotels, restaurants, banks, governmental offices, the professions, and other similar occupations. When one realizes that Los Angeles County alone has 6,729 service stations and 5,789 grocery stores, the importance of these activities as a source of jobs is emphasized.

Figure 2 compares employment patterns in California in 1949 with the United States as a whole in that same year. In 1949, manufacturing employment accounted for 28 per cent of the United States total, but was only 18 per cent of the California total. Trades and services, on the other hand, accounted for 43 per cent of the United States total, but were 58 per cent of the California total.

The contrast is significant in that it reflects the present nature of western economy. It also shows the differences between western business and the average for the nation.

As previously mentioned, the development has been uneven during this period, as is to be expected in any rapidly growing area. Obviously, the business activities which appeared and expanded in the West were those which found an economic advantage in this section. Other firms found it more advantageous to continue supplying this market from existing plants—at least for the time being. But still others are not participating because their managements have been unaware of the newly-opened opportunities in this region, which are far greater than ever before.

Prewar, much of western industry was oriented toward a secure raw material base. The manufacture of food products, the petroleum industries, paper and paper products, lumber manufacturing, and mining were well established and had developed a host of satellite industries. These still make up the hard core of western industry.

There also has been an advantage for industries which, because of the low specific value of their products, always locate close to their markets. In addition, job shop operations producing specialties or doing repair and other service work constituted a large part of western industrial activity. Finally, climate influenced the location and development of the motion picture and aviation industries, and has inspired a styling from clothes to furniture, which the entire nation today associates with outdoor living.

But other industries have been slow in developing. This was true particularly of industries which required large groups of specially skilled workers; or those in which the economies of large-scale production offset the extra cost of transportation to western markets.

FACTORS IN PLANT LOCATION

THE ECONOMICS of plant location presents an ever-shifting scene. What was uneconomic for this area ten years, or even five years, ago may not necessarily be so today. Consider the following factors.

Western markets for all types of goods have expanded rapidly since the war and are continuing to expand today, and the growing market potential is adding constantly to a growing list of industries feasible for this area. The national trend toward decentralization, which has been given impetus by growing transportation costs, is aiding industrial growth in the West. The new population includes large pools of skilled workers who were not available to western industry previously.

The expanding basic heavy industries are offering local supplies of raw materials available for manufacture. Basic aluminum alone has made possible hundreds of local manufacturing operations which were not thought of before the war. The new basic industries not only make possible, but often require, a host of satellite industries. They also require a network of suppliers of services and products of all kinds. Shorter supply lines between factory and user are needed today, because distributors are loath to carry large inventories, and are demanding quick deliveries from the factories. New West Coast research facilities have been established which are available to aid the growth of industries. They have also developed new products and proc-

Figure 3. Location of steel mills and blast furnaces on the Western Slope

Figure 4. Operations during a "tapping" of open hearth furnaces at the Pittsburg, Calif., mill of United States Steel's Columbia Steel Company must move swiftly. Here crusts of slag are seen beginning to form as it floats atop the molten steel in the ladle and drains off into two pots on the floor. Crane hooks attached to the 90-ton ladle will remove it to a position where its contents can be poured via the bottom pouring process into groups of ingot molds

esses which may make possible the establishment of new industries in the area.

Finally, there is an intangible which should not be discounted; the West is enthusiastic, is looking ahead, is progressive and expects to continue to develop in the future, as it has in the past. However, the West has not yet consolidated all of its gains. One section of the economy of the region cannot advance too far ahead of the rest. An industrial balance must be maintained as the area progresses. A supplier, for example, cannot outdistance his market too far and stay in business.

In seeking the further development of the West, a balance should be sought that fits the nature of western economy. There should not be too much concern about the lack of certain types of industries which for the present do not fit economically into its industrial pattern. The West cannot be a small composite of the national pattern—no single region is. The western states must take the fullest advantage possible of their opportunities; they must take stock of their assets and know their markets; they must capitalize to the fullest extent upon their natural advantages.

It should be clear that industries cannot be expected to locate in the West without having a high degree of investment confidence in its future. Plant location decisions rest upon exhaustive analyses of markets, buying power, natural resources, labor supply, distribution facilities, and other supporting inducements. One of the nation's largest automobile manufacturers recently estimated that every newly created job costs that industry a minimum of $10,000, and this may even be exceeded in industries requiring heavy equipment and skilled workers. However, consider the advantages of attracting a new industry into a community.

It is estimated that an average plant employing 150 workers in a community represents approximately $500,000 in manufacturing investment, and accounts for an estimated yearly sales of a quarter of a million dollars. At the same time, this plant supports, not only the workers and their families, but nearly 400 occupied homes, 33 retail stores, 320 automobile and service facilities, 24 professional people, 18 school teachers, and other essential sources of service and supply. This indicates roughly what a new plant can mean to a community.

IRON AND STEEL EXPANSION IN THE WEST

Since 1920, steel ingot capacity has increased more than eight times—from 515,000 net tons to 4,380,000 in 1950. Although the greatest growth has occurred dusing the past ten years, there was a steady prewar increare—893,000 net tons in 1930 and 1,038,000 net tons in 1940. Figure 3 indicates where the blast furnaces and steel mill facilities are located in the West.

Based on an average for the five prewar years, 1936–40, 32 per cent of the steel consumed in the West came in by rail and 41 per cent came in by ship. Only 28 per cent was produced by western mills. In 1948, however, western mills produced 56 per cent of total local consumption, twice the share of prewar years. Rail movement inbound retained its share at 32 per cent, but intercoastal movements dropped off sharply. Consumption has more than doubled, but local production is $4^1/_2$ times what it was in the prewar years. Expressed in tons, total western consumption of steel prewar was approximately 2,200,000 tons, and in 1948, approximately 5,000,000 tons. Hence it is likely that local availability of steel mill products will continue to grow provided other industry grows with it.

I am optimistic about the future of the West. However, one must face realistically the fact that there are some obstacles in its path. The section is industrially immature. The lack of many types of satellite industries inhibits its growth. There is an impending shortage of water in some parts of the area which looks very serious. There are internal transportation problems brought about by the vast distances between population centers. These are just some of the obstacles facing the West today, but these obstacles will not stop the growth of this area. These problems will be solved just as other problems have been solved in the past.

There has been a tendency to mock the optimist. This is a national disease, and I think the source of infection can be traced to the Marxian philosophy which argues that the frontier has been exhausted, that we are not going any farther, and that we all may as well just sit down and divide up our gains. I believe, however, that there is more distance to be traveled on the road to progress than has been traveled already. We never will journey over the horizon. The frontiers of opportunity will continue to be pushed back by men of vision and enterprise and progress will continue.

High-Interrupting-Capacity Low-Voltage Power Fuses

C. L. SCHUCK
ASSOCIATE AIEE

CARTRIDGE FUSES are used principally on a-c circuits, but they do not have interrupting ratings ther than may be implied by their having met the 10,000-mpere d-c short-circuit test which forms part of the 'Standard for Fuses."[1] The growth and interconnection of many industrial and shipboard circuits, in which fault urrents may be considerably greater than 10,000 amperes, as created a demand for fuses with proved adequate nterrupting capacity.

To provide fuses satisfying modern requirements, a ew line of fuses has been developed of standard 250- and 00-volt sizes, with a-c interrupting ratings of 100,000 ms amperes (total including d-c component) at 60 cycles. Their development was carried out utilizing techniques rom high-voltage power-fuse design and the experience of European manufacturers, who have made low-voltage uses of moderately high interrupting capacity. The use of improved insulating and arc-quenching materials leveloped in the United States and a detailed study of he factors affecting the interruption of low-voltage high-urrent arcs in granular inert fuse fillers made possible he interrupting abilities achieved.

Interruption of fault currents is accomplished without listurbance of any kind external to the fuse. This is nade possible by the current-limiting manner of interrup-ion; the rapid arc-quenching action of the fuse does not ermit the full available short-circuit current to pass. Figure 1 shows reproductions from four typical oscillograms aken during interruptions of high short-circuit currents. The current-limiting effect is seen to be more pronounced vith the lower current ratings. In addition to these peak urrent values, measurements made from the oscillograms proportional to the heating effect of the current passed by he fuse may be used in calculating melting, arcing, and otal "let-through" effective current $\int i^2 dt$.

The voltage traces of the oscillograms show relatively low rates of rise and low peak values of transient recovery

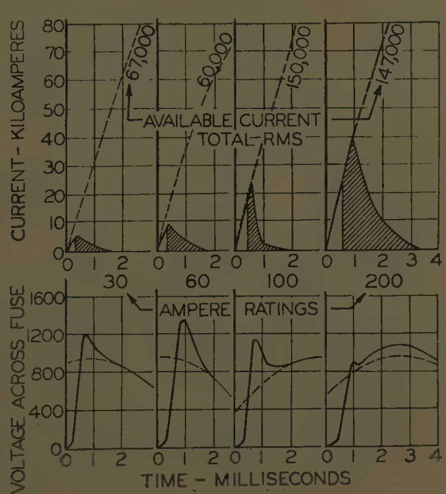


Figure 1. Short-circuit tests of high-interrupting-capacity cartridge fuses at 660 volts rms, 60 cycles. Melting time-current areas—clear; arcing time-current areas—cross hatched; generated voltage—dotted

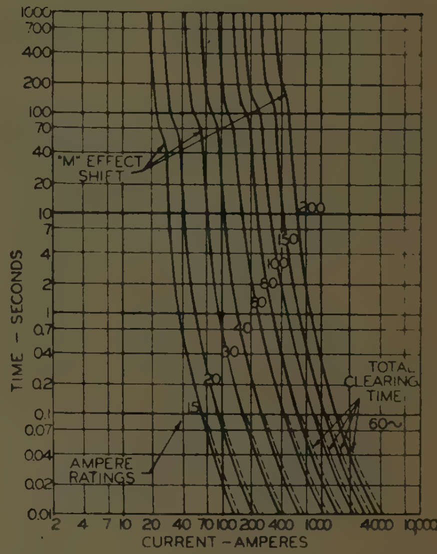


Figure 2. Melting time-current curves. Improved overload protection results from "M" effect obtained by the addition of small globules of a tin-rich alloy to the active section of the elements

voltage across the fuse. The average of the voltage peaks in the four tests of Figure 1 is less than 1,200 volts and therefore is easily tolerated by apparatus having 600-volt-class insulation.

Melting and total clearing time-current curves (see Figure 2) essential for making applications are also based on tests and measurements from oscillograms. For the region of low currents and long melting times, the elements of the new line of fuses were adjusted to make the ratings comply with the "Standard for Fuses."[1] This assures that overload protection will be afforded wire sizes commonly used with given ampere ratings, and in regard to short-circuit protection, calculations show only a few degrees rise in wire temperature resulting from the passage of the effective current $\int i^2 dt$ when the fuse interrupts a high short-circuit current. Similarly, once ampere ratings of fuses have been selected for a protective scheme to give desired selective operation in the region of moderate values of fault current, a check of melting and total $\int i^2 dt$ values pertaining to the interruption of high short-circuit currents will show whether there is sufficient spread in the ratings chosen. The criterion is that the $\int i^2 dt$ involved in both the melting and arcing of the protecting fuse shall be less than the $\int i^2 dt$ required to melt the protected fuse. The latter requirement is frequently more demanding of spread between ampere ratings, but when satisfied will provide for the isolation of only a minimum portion of the circuit in the event of a fault.

REFERENCE

1. Standard for Fuses. Underwriters' Laboratory, Inc., New York, N. Y., fifth edition, January 1948.

Digest of paper 50-127, "A New High-Interrupting-Capacity Low-Voltage Power Fuse," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Great Lakes District Meeting, Jackson, Mich., May 11–12, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

C. L. Schuck is with the General Electric Company, Philadelphia, Pa.

Multistation Control, Telemetering, and Communication on Single-Frequency Carrier

W. A. DERR
MEMBER AIEE

T. C. WREN

J. V. KRESSER
MEMBER AIEE

A centralized control system utilizing power-line carrier was recently installed by the Sierra Pacific Power Company. This single-frequency multistation system is used for supervisory control, as well as selective telemetering and communication.

POWER-LINE carrier and associated equipment were recently placed in service by the Sierra Pacific Power Company for the centralized control of part of the system. In planning this centralized control system, consideration was given to the use of telephone-line wires, power-line carrier, and microwave radio to provide the necessary interconnecting channels. Economic considerations led to the selection of power-line carrier.

This first use of power-line carrier equipment on the Sierra Pacific Power Company system exemplifies the efficient use of carrier equipment by combining multistation supervisory control, selective telemetering, and communication on a single-frequency channel. A multistation supervisory control system is one in which more than one station is operated from a common set of equipment at the controlling station. The system to be described requires no audio-tone modulating equipment since only a single signal-receiving relay is required at the controlling location and at each controlled location.

POWER SYSTEM

FIGURE 1 is a partial single-line diagram of the Sierra Pacific Power Company system showing the stations involved in this centralized control installation. The approximate direct-line and transmission-line distances between the stations are also shown in Figure 1.

Equipment is now in service which provides for the remote operation of the Farad Hydro Station, the Verdi Hydro Station, and the Virginia City Substation. The equipment recently installed provides for the control of these three stations from the Washoe Hydro Station. All system dispatching is done from the Washoe Hydro Station. This remote-control system will be extended to include another station in the near future.

The Farad Hydro Station has two 1,750-kva generators providing a normal output of 2,900 kw and 2,100 reactive kilovolt amperes. The Verdi Hydro Station has one 3,000-kva generator providing a normal output of 2,300 kw and 1,200 reactive kilovolt amperes. The output of the Farad Plant is determined by the forebay level at Farad. The output of the Verdi Plant is determined by the river level. Both plants carry base load which must be adjusted periodically to conform to the water level. The water level at both stations is determined by the flow of water in the Truckee River. The reactive kilovolt-ampere output of the plants is determined from the system voltage conditions.

In Figure 2 the carrier, supervisory control, telemetering, and communication components which have been applied at the Washoe, Farad, and Verdi Hydro Stations and the Virginia City Substation are shown in block diagram form.

POWER-LINE CARRIER EQUIPMENT

EXACTLY duplicate standard carrier assemblies are installed at each of the four locations shown in Figure 2. These standard assemblies are exactly the same as those which are applied for carrier relaying of the distance-measuring type.[1,2] The assemblies are also the duplicate of those used for phase-comparison relaying except for the omission of a control unit which is required for phase-comparison relaying.[3] All of the carrier equipment is operated from 125-volt station batteries.

The carrier equipment at each location is mounted on a standard relay rack in an indoor-type cabinet. The assembly consists of individual transmitter, receiver, and modulator panels and a test-meter unit.

The transmitter panel consists of a Colpitts oscillator (one tube) and a 6-tube push-pull amplifier. The amplified carrier-frequency output is fed into an iron-cored radio-frequency transformer whose secondary couples the carrier to the line through the line tuning unit and coupling capacitor. The transmitter has a frequency range of 50 to 150 kc and a frequency stability of one-half per cent. The transmitter has a nominal power output of ten watts.

The receiver panel consists of a narrow-band saturated receiver and a broad-band receiver. The narrow-band receiver is used for all unmodulated carrier signals such as supervisory control and telemetering impulses. The broad-band receiver is suitable for the high-quality reception of speech. The frequency range of both receivers is 50 to 150 kc. On this installation both receivers are tuned to the same frequency. The narrow-band receiver will operate through an attenuation of 30 decibels when used with a 10-watt transmitter. The broad-band receiver will

Essentially full text of paper 50-175, "Multistation Supervisory Control, Telemetering, and Communication on Single-Frequency Carrier Channel," recommended by the AIEE Committees on Carrier Current and Substations and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

W. A. Derr is with the Westinghouse Electric Corporation, Pittsburgh, Pa.; T. C. Wren is with the Sierra Pacific Power Company, Reno, Nev.; and J. V. Kresser is with the Westinghouse Electric Corporation, San Francisco, Calif.

perate through an attenuation of 50 decibels when used vith a 10-watt transmitter.

The modulator panel has relays, voltage-dropping resis-ors, and a telephone handset jack-mounted on it. It is lesigned for use with a push-to-talk telephone handset. The voltage-dropping resistors furnish proper microphone current and operating voltages for the relays. The relays and contacts are wired so that the carrier transmitter can be keyed when the telephone push-to-talk key is operated.

The test-meter unit is a portable assembly of instruments or routine circuit testing. It can be mounted in the carrier cabinet. All of the carrier panels have test jacks in the main circuits to provide for the measurement of currents and voltages with the test-meter unit.

The power-line carrier equipment operates from phase to ground. As shown in Figure 2, the carrier transmitter and receiver at Washoe are coupled to the 60-kv lines to Farad as well as to the two 60-kv lines to Virginia City. Single-frequency carrier line traps are installed in each of these lines so that an essentially fixed impedance is pre-sented to all carrier signals regardless of switching opera-tions at Washoe. This is the only location at which carrier line traps are used. The carrier equipment is coupled to both 60-kv lines between Washoe and Virginia City to obtain additional reliability.

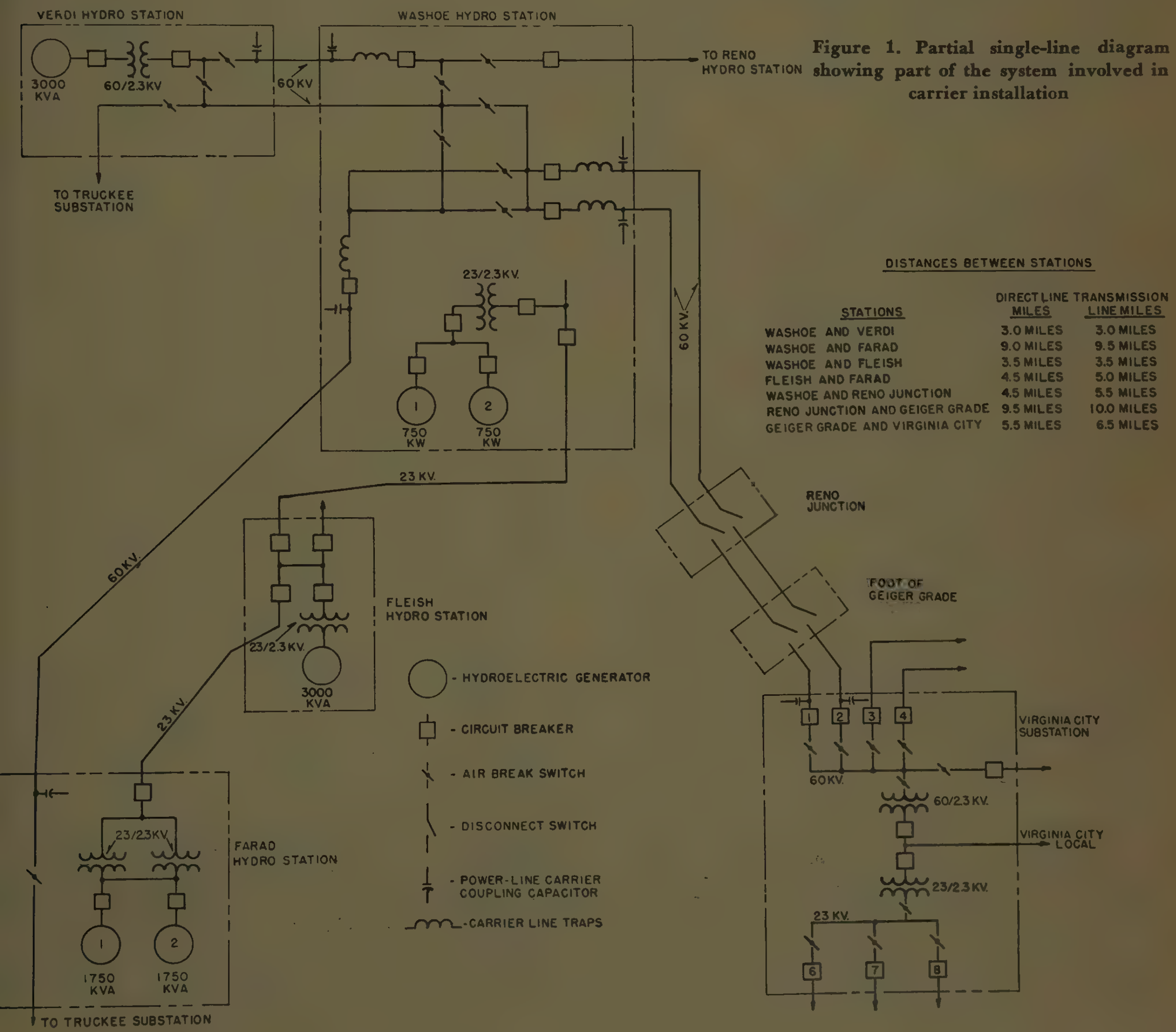
Since no attenuation data were available and since there is no other carrier on the system, it was arbitrarily decided to try operation at a frequency of 100 kc. A satisfactory signal was obtained at all locations, and the system is still operating at this frequency.

There was no problem involved in tuning the parallel circuits at Washoe. The 4-line tuners are each connected to the carrier equipment by a separate coaxial cable. Each of the lines was tuned independently of the others, and it was found that the division of the radio-frequency current was fairly even. No difficulty is anticipated when another line out of Washoe is added to this carrier system for the control of a fourth station.

A satisfactory signal is obtained at Virginia City with either of the two 60-kv lines out of service.

SUPERVISORY CONTROL EQUIPMENT

THE SUPERVISORY control equipment applied is of the direct-selection all-relay coded-impulse type.[4] This



DISTANCES BETWEEN STATIONS

STATIONS	DIRECT LINE MILES	TRANSMISSION LINE MILES
WASHOE AND VERDI	3.0 MILES	3.0 MILES
WASHOE AND FARAD	9.0 MILES	9.5 MILES
WASHOE AND FLEISH	3.5 MILES	3.5 MILES
FLEISH AND FARAD	4.5 MILES	5.0 MILES
WASHOE AND RENO JUNCTION	4.5 MILES	5.5 MILES
RENO JUNCTION AND GEIGER GRADE	9.5 MILES	10.0 MILES
GEIGER GRADE AND VIRGINIA CITY	5.5 MILES	6.5 MILES

Figure 1. Partial single-line diagram showing part of the system involved in carrier installation

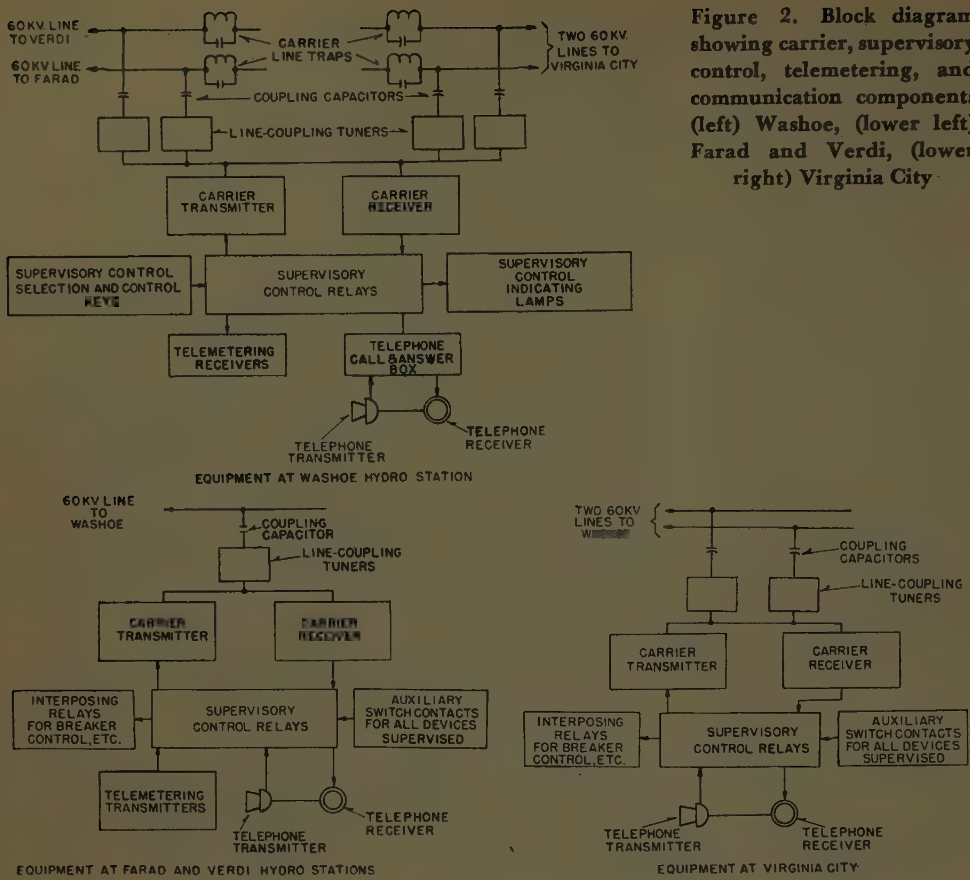


Figure 2. Block diagram showing carrier, supervisory control, telemetering, and communication components (left) Washoe, (lower left) Farad and Verdi, (lower right) Virginia City

type of system employs a series of impulses transmitted at the rate of approximately 15 per second for all selection and control codes. Check or verification codes are used to insure proper selections. This type of system requires only a single signal-receiving element at each station. Only such a single-signal system can be used for the control of several stations on a single-frequency carrier channel.

The supervisory escutcheons are arranged in a mimic bus arrangement at the Washoe Hydro Station to depict the essentials of the power system. An individual escutcheon is provided for the control and supervision of each circuit breaker, for each selective telemetered indication, and so forth.

The supervisory control provides for the control and supervision of the circuit breakers at Virginia City Substation and for all of the essential functions at the Farad and Verdi Hydro Stations. The supervisory control also provides a selective telephone-ringing function to each of the controlled stations. Following is a complete list of the functions provided at the Verdi Hydro Station. Each such complete function is usually referred to as a point of the supervisory control.

1. Start-stop control of generator with supervision of master relay.
2. Control of generator field rheostat with telemetering of reactive kilovolt-ampere output.
3. Control of generator-governor synchronizing motor with telemetering of generator kilowatt output.
4. Control and supervision of 60-kv circuit breaker.
5. Control and supervision of generator circuit breaker.
6. Telemetering of forebay water level.
7. Supervision of alarms for which generator shuts down.
8. Supervision of alarms which do not shut down generator.
9. Telephone ringing.

TELEMETERING EQUIPMENT

IMPULSE-TYPE telemetering equipment is used for the selective telemetered indications previously listed.[5,6] Rate of impulse telemetering equipment is used for the indications of kilowatts and reactive kilovolt-amperes. The rate of impulsing is between 80 and 220 per minute. The left-hand reading on the receiver is obtained with a rate of 80 impulses per minute, and the right-hand or full-scale reading is obtained with a rate of 220 impulses per minute.

Since the readings are selective, a single transmitter is used at the Farad and Verdi Hydro Stations for telemetering kilowatts and reactive kilovolt amperes. The supervisory control equipment connects the transmitter to the proper potential and current-transformer circuits. A reactive-component compensator is automatically connected in the potential circuits to the transmitter by the supervisory control equipment for telemetering reactive kilovolt amperes.

At the Washoe Hydro Station, a single receiver is provided for all kilowatt indications, and a single receiver is provided for all reactive kilovolt-ampere indications.

Duration of impulse-type telemetering equipment is used for the selective indications of water level. The transmitters are of the pressure-bulb type. With this system, the reading obtained is based on the length of impulse transmitted during each 5-second cycle.

AUTOMATIC SWITCHING EQUIPMENT

IN PROVIDING for the remote operation of the Farad and Verdi Hydro Stations it was necessary to add certain automatic-switching and protective equipment at each of these stations.[7] The method of operation provided for the two stations is somewhat different.

At the Farad Hydro Station, an automatic electronic synchronizer, a speed matcher, and a voltage-balance relay are provided. Upon receipt of a starting signal from the supervisory control equipment, all of these devices are automatically connected to the generator to be started. Thus the speed and voltage of the generator are automatically made to match the system frequency and voltage. The automatic synchronizer causes the generator circuit breaker to close when the instantaneous frequency differ-

ice and the phase-angle difference are satisfactory for oper synchronizing.

The control of the Verdi Hydro Station is based on all nchronizing being done on the circuit breaker at the 'ashoe end of the line. Therefore, no automatic synronizing or speed-matching equipment is used at the erdi Hydro Station. The operator at the Washoe Hydro ation is able to start the generator at the Verdi Hydro ation and to control individually the generator and line rcuit breaker. The operator can also control the speed id voltage of the generator at the Verdi Hydro Station to e able to effect manual synchronizing of the circuit breaker the Washoe Hydro Station.

After the generators at the Farad and Verdi Hydro Staons are connected to the system, the operator at Washoe in control the kilowatt and reactive kilovolt-ampere outit of the machines.

OPERATION OF REMOTE-CONTROL SYSTEM

THE SUPERVISORY control system applied in this centralized control installation can provide for an ultimate f 100 functions or points. Two series of impulses, both of hich are automatically checked, are required for the election of each individual point. The first series of imulses selects a group of ten points, and the second series of npulses selects the individual point in the group of ten oints. The necessary number of groups to provide for the esired number of functions is assigned to a particular ation.

The two series of impulses required for the selection of an dividual point are designated as group- and point-selecon codes. The corresponding check or verification codes re designated as group- and point-check codes. In this istallation, the minimum number of impulses for any group election code is seven. This eliminates the possibility of ny actual group selection resulting from random interrence which could operate a carrier-receiver relay. he corresponding group-check codes are in all cases six npulses less than the group-selection codes. The pointelection and point-check codes are the same and may have om one to ten impulses. Since the impulses are transitted at the rate of approximately 15 per second, the ongest selection time for any point of the ultimate system less than four seconds.

The group-selection codes now in use are as follows:

Verdi	7 and 8 impulses
Farad	9 and 10 impulses
Virginia City	11 and 12 impulses

If a selection key is operated at Washoe, the group- and oint-selection codes originate at Washoe and the groupnd point-check codes originate at the station selected. n the case of an automatic operation reporting from one of he remotely controlled stations, the group- and pointelection codes originate at the remote station and the groupnd point-check codes originate at Washoe.

For control functions and for the supervision of devices imilar series of impulses are used. The number of such npulses is the same for all points since only one point can be elected at a time.

Since the carrier transmitters and receivers are tuned to the same frequency at all locations, keying a transmitter at one or more locations results in operation of the single carrier-receiver relay at every station. This party-line arrangement makes it possible for the supervisory control to select a particular station and simultaneously to lock out all other stations. The group-selection code is recognized as a lockout code by all stations except the one being selected. These stations remain locked out until a reset impulse is transmitted from Washoe at the end of a complete function. The reset impulse is approximately one-fourth second long. Receipt of a carrier impulse of this length or longer at any station releases a point which may have been selected at that station or unlocks that station if it had been

Table I. Supervisory Control Impulsing for Typical Operations

Washoe (Controlling Station)	Verdi (Controlled Station)	Farad (Controlled Station)	Virginia City (Controlled Station)
A. Closing of Circuit Breaker at Virginia City from Washoe			
Group Selection Code → (11 Impulses)			
	Locks Out	Locks Out	Group Selected
			Group Check Code ← (5 Impulses)
Group Check	Remains Locked Out Until Single Long Reset Impulse Received	Remains Locked Out Until Single Long Reset Impulse Received	
Point Selection Code → (3 Impulses)			
			Point Selected
			Point Check Code ← (3 Impulses)
Point Checked			
Close Control Code → (5 Impulses)			
			Circuit Breaker Closes
			Close Supervision Code ← (5 Impulses)
Lamp Indication Changed			
Reset Impulse →			
System Restored to Normal At-Rest Condition			
B. Reporting of Automatic Circuit-Breaker Trip from Farad to Washoe			
		Group Selection Code ← (9 Impulses)	
Group Selected	Locks Out		Locks Out
Group Check Code → (3 Impulses)			
	Remains Locked Out Until Single Long Reset Impulse Received	Group Checked	Remains Locked Out Until Single Long Reset Impulse Received
		Point Selection Code ← (1 Impulse)	
Point Selected			
Point Check Code → (1 Impulse)			
		Point Checked	
		Trip Supervision Code ← (3 Impulses)	
Lamp Indication Changed			
Reset Impulse →			
System Restored to Normal At-Rest Condition			

locked out by selection at another station. A reset impulse restores the entire supervisory control system to its normal at-rest condition so that it is ready for another selection.

Table I*A* indicates the impulsing which results if the circuit breaker at Virginia City Substation, which is assigned a group-selection code of 11 impulses and a point-selection code of three impulses, is selected and closed. Table I*B* indicates the impulsing for the automatic tripping of a circuit breaker at Farad Hydro Station which is assigned a group-selection code of nine impulses and a point-selection code of one impulse.

As indicated in block-diagram form in Figure 2, the supervisory control relays at each station are interposed between the carrier equipment and all of the services provided. This makes it possible to give preference to the important supervisory control functions rather than to the telemetering or communication services.

SELECTIVE TELEMETERING

Operation of a point-selection key for any of the selective telemetered indications results in the automatic transmission of group-selection, group-check, point-selection, and point-check codes of impulses as described for the selection of a circuit-breaker control point. However, at the conclusion of the point-check code, the proper telemetering transmitter has its keying contact connected to the carrier transmitter, and the proper telemetering receiver is connected to receive the carrier impulses. Thus, an indication is obtained as soon as the point is selected.

The circuits are arranged so that the telemetering impulses, which are long with respect to the length of the supervisory control impulses, do not cause the point to be released either at the Washoe controlling station or at the controlled station selected. However, the telemetering impulses do reset the other controlled stations which were locked out when the group-selection code was transmitted.

The telemetered indication may be maintained as long as desired. Operation of the reset key results in the supervisory-control reset impulse being transmitted at the termination of a telemetering impulse which may have been in progress at the time. Operation of the carrier-receiver relay at the station selected without the telemetering transmitter contact being closed results in the selected point being released and the entire system restored to normal.

In the case of points in which a control function is combined with the selective telemetering, the control impulses from the Washoe Hydro Station are transmitted during the off period of the telemetering impulses. The control is of the increment type with the control circuits at the controlled station being energized for a definite period of time for each operation of a control key at the Washoe Hydro station. An arrangement is provided so that the control increment for each of the devices controlled is individually variable. It is possible for the operator at the Washoe Hydro Station to obtain accurately the desired kilowatt and reactive kilovolt-ampere output of the generators since a telemetered indication is obtained while the controlling is being done.

Since the continuous transmission of carrier from any station with such a single-frequency carrier system would make the entire system inoperative, a timing circuit is provided to disconnect automatically a telemetering transmitter which keys the carrier transmitter continuously due to a failure in the telemetering transmitter or loss of a-c power on the transmitter.

COMMUNICATION

The supervisory control provides for selective ringing from the Washoe Hydro Station to any of the three stations controlled. It also provides for any of the controlled stations calling the operator at the Washoe Hydro Station. The telephone ringing is accomplished by points of the supervisory control.

A telephone deskset and a telephone call and answer box is located in the Washoe Hydro Station. The call and answer box has a telephone key and lamp for each of the controlled stations. To initiate a telephone call from Washoe, it is only necessary to operate the telephone call key for the desired station and to lift the telephone handset from the cradle. This results in the automatic transmission of the proper group- and point-selection codes from Washoe and the corresponding check codes from the station being called. When the point-check code is received at Washoe, a control code is automatically transmitted to ring the telephone bell at the station being called. When the call is answered by the removal of the telephone handset from the cradle at the called station, a supervision code is transmitted which is followed by a reset impulse from Washoe to restore the entire supervisory control system to the normal at-rest condition. When the supervisory control equipment resets, circuits are completed from the telephone to the carrier equipment at Washoe as well as at the station called. This establishes communication of the push-to-talk type between Washoe and the station called. Operating the push-to-talk key on either telephone handset keys the carrier transmitter at that location and the telephone transmitter can then modulate the carrier. This is the same type of communication which is provided on the usual single-frequency carrier-protective relaying installation.

Calling the operator at Washoe from one of the controlled stations is accomplished in a similar manner. It is only necessary to remove the telephone handset from the cradle at the controlled station to initiate a call to Washoe. The telephone at the controlled stations is mounted on a supervisory control panel. When the supervision code is received at Washoe, the telephone bell is sounded and the call lamp indicating which station is calling is lighted. To answer the call, the operator removes the telephone handset from the cradle and operates the telephone call key for the station making the call. The supervisory control system then automatically resets and conversation can start.

With this communication system it is possible for the operator at Washoe to perform the necessary ringing functions to establish communication between two or more of the remotely controlled stations.

After communication is established, the supervisory control system is locked out while a telephone push-to-talk key is operated at any of the stations. However, the supervisory system takes control at the first instant that no telephone push-to-talk key is operated. Thus, if a circuit

reaker is tripped by a protective relay operation at any ation, it will report its new position to Washoe in the usual anner at the first pause in the conversation. The first upervisory control impulse disconnects the telephone from e carrier equipment at each station and prevents the arting of carrier by a telephone push-to-talk key until the ntire supervisory control function is completed. The onversation can be immediately resumed after the several econds required to complete supervisory control function.

The circuits for keying the carrier transmitters with the elephone push-to-talk keys are arranged so that it is only ossible to transmit an impulse long enough to constitute a eset impulse for the supervisory control regardless of how hort a period of time the push-to-talk key is operated. This makes it impossible to step the supervisory control from s normal at-rest condition.

CONCLUSION

THERE are many installations of power-line carrier for supervisory control, telemetering, and communication ervices. In most of these installations a separate channel is sed for each one of these services. In quite a number of ases carrier relaying has been combined with any of hese three services on a single 2-terminal channel.[8] There re also installations of supervisory control combined with elemetering, and of supervisory control combined with ommunication on a 2-terminal channel. However, the nstallation described was the first in which a single-frequency channel was used for multistation supervisory control, telemetering, and communication. This provides the most economical possible arrangement since a minimum of carrier equipment is required.

The fact that only a single carrier frequency is required for this entire system is not particularly important in this instance, since no other carrier is in use on the Sierra Pacific Power Company system. However, this is an extremely important consideration in many sections of the country where it is becoming increasingly difficult to choose new frequencies due to the large number of channels already in use.

The carrier-operated remote-control installation described has simplified system dispatching and improved system operation.

REFERENCES

1. A New High-Speed Distance-Type Carrier-Pilot Relay System, **E. L. Harder, B. E. Lenehan, S. L. Goldsborough.** *Electrical Engineering* (AIEE *Transactions*), volume 57, January 1938, pages 5–10.
2. The Application of Power-Line Carrier, **R. C. Cheek.** *Power Plant Engineering* (Chicago, Ill.), November 1945.
3. A New Carrier Relaying System, **T. R. Halman, S. L. Goldsborough, H. W. Lensner, A. F. Drompp.** *Electrical Engineering* (AIEE *Transactions*), volume 63, August 1944, pages 568–72.
4. By a Flick of the Finger, **W. A. Derr.** *Westinghouse Engineer* (Pittsburgh, Pa.), November 1945.
5. Telemetering Circuits—Metallic and Carrier, **M. A. Bostwick.** AIEE *Transactions*, volume 67, part II, 1948, pages 1081–8.
6. Telemetering (book), **P. A. Borden, G. M. Thynell.** Reinhold Publishing Company, New York, N. Y. 1948. Chapter 7.
7. Automatic Control of Hydroelectric Generating Stations, **M. J. Brown, W. A. Derr.** AIEE *Transactions*, volume 66, 1947, pages 343–55.
8. A Versatile Power-Line-Carrier System, **H. W. Lensner, J. B. Singel.** *Electrical Engineering* (AIEE *Transactions*), volume 63, 1944, March section, pages 129–33.

Handling Power System Problems on an A-C Network Calculator

P. O. BOBO
MEMBER AIEE

Calculating board networks have become more and more complicated as power systems have grown and expanded. As a greater number of and more complex problems have been submitted for solution, new techniques have been employed and the boards themselves have been improved.

USE of the a-c calculating board has become standard practice among power companies in the United States. It is used or the solution of operating roblems, planning new additions to systems, and for tudying proposed interconnections. It is becoming a major tool in the development f system loss formulas,[1] and no doubt will see much service in problems of economic plant loading.[2]

Power system growth has been rapid since the war. The complexity of calculating board networks has increased roportionately. Because of this fact, coupled with the increase in demand for solution of power system problems by a-c network calculators, new techniques of procedure have been developed and additional features have been added—all of which increase the efficiency of the boards.

A technique of obtaining approximate self-regulation of generator output in balancing load studies has been developed. This is done by using arbitrary values of reactance behind the generator terminals. The reactance values are inversely proportional to the desired generator output and are set to values equal to 30 to 40 times the ratio of the base megavolt-amperes to the megavolt-amperes desired output. For example, the reactance of a generator with a small output, say 10 per cent of base

ssentially full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950.

. O. Bobo is with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

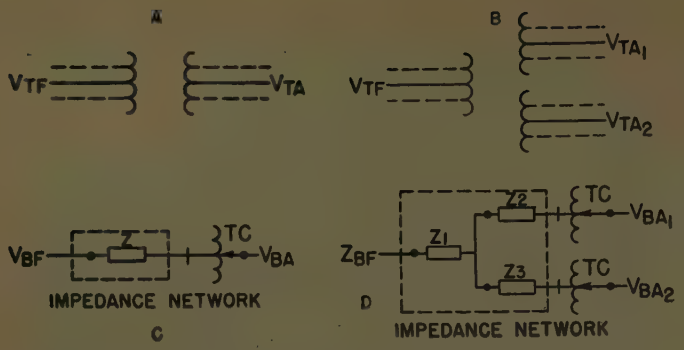


Figure 1. Representation of power system transformers. Single-line diagrams, (A) a 2-winding transformer, (B) a 3-winding transformer; (C and D) impedance network connections of the above transformers to board tap-changing autotransformers, TC.

output, would be set approximately 300 per cent; that of a generator with 200 per cent base output would be set for about 15 per cent, and that of a "swing" machine would of course be set at zero. Hence, any load fluctuations during the balancing of a given condition would tend to be mostly absorbed by the so-called "swing" machine with the small remainder distributed uniformly on the other generator units.

By such use of these internal reactances, one operator can very readily balance a load-flow condition of a network using all 22 of the generator units.

One of the most confusing problems among engineers using the calculator has been the representation of power-system transformers.

The upper part of Figure 1 shows two 1-line diagrams, *A*, a 2-winding transformer, and *B*, a 3-winding transformer. It is assumed here that the left windings of each transformer do not have taps and that the right windings do have taps.

Transformers are represented on the board by elements of impedance and variable tap-changing autotransformers. The confusion, heretofore mentioned, lies in the method of interconnecting these elements. To remove this confusion and to standardize the connections of these elements, the following method is recommended.

For any transformer to be represented on the board, refer to one winding as the fixed winding, usually a winding without taps, or if all windings have taps the one which will require the fewest number of tap changes during the board studies. Refer to the other winding (or windings) as adjustable windings. In Figure 1 then, the left windings of each transformer become the fixed windings, and the right windings become the adjustable windings. Refer all impedances to the fixed side of the transformer. The lower diagrams in the figure, therefore, show the impedance networks on the left or fixed side. The impedance computations are then made by the formula

$$Z_B = \%Z_T \frac{kva_B}{kva_T}\left(\frac{kv_{TF}}{kv_{BF}}\right)^2 \qquad (1)$$

where Z_B is the board impedance in ohms, per cent Z_T is the transformer winding per cent impedance at rated kilovolt-amperes, kva_B is the base kilovolt-amperes, kva_T is the transformer winding rated kilovolt-amperes, kv_{TF} is the transformer rated tap voltage in kilovolts of the adjustable winding, and kv_{BF} is the base voltage in kilovolts of the fixed side of the autotransformer. This ratios the given per cent values of the transformer to the megavolt-ampere board base and corrects for any difference between the rated voltage of the fixed winding of the actual transformer and the board base voltage on the fixed side of the transformer. Again referring to the lower diagrams, the tap-changing autotransformers are now connected to each terminal of the impedance network corresponding to an adjustable winding. Note that the adjustable side of each autotransformer corresponds with the adjustable side of the actual transformer, which means a tap change of the actual transformer is obtained by a tap change in the same direction on the tap-changing autotransformer. Most previous practices were to place them on the low-voltage side of the transformer impedance with the adjustable side toward the direction of boost. This practice confused many engineers because the direction of the actual transformer tap change most generally did not conform with the direction of the board autotransformer setting. The tap settings for the tap-changing autotransformer are determined from the formula

$$TS = \frac{kv_{TA}}{kv_{TF}}\frac{kv_{BF}}{kv_{BA}} 100 \qquad (2)$$

where TS is the tap setting of board autotransformer in per cent, kv_{TA} is the transformer rated tap voltage in kilovolts of the adjustable winding, and kv_{BA} is the base voltage in kilovolts of the adjustable side of the autotransformer. These settings correct for the ratio difference between the actual transformer winding voltages and the board base voltages of the corresponding sides of the transformer.

The technique of balancing system load studies has been changed greatly by the addition of varmeters to the complement of generator instruments and voltmeters[3–5] across the load impedances, Figure 2. These additions have removed from the master desk operator the major directing burden of balancing the board for various system conditions and given it to the man at the controls who now has direct supervision of all generators and loads. By these means he can tell at a glance the division of reactive load among the various generating plants for given conditions of loading and the voltage conditions at all system load points.

Previous to the additions of varmeters and load voltmeters, it was necessary for the master instrument operator to check each generator and each load, one at a time, and verbally relay instructions of adjustment to the man at the controls. This, as you can see, was time-consuming.

Figure 2 shows a 1-line diagram of connections for one pi-line unit, and Figure 3*B* shows four units. Such circuits are used for representing high-voltage transmission lines with distributed capacitance. Note that the metering points *M* are outside the pi-connections and thus permit direct metering of true terminal values of real and reactive power. On the older boards that do not have pi-line cir-

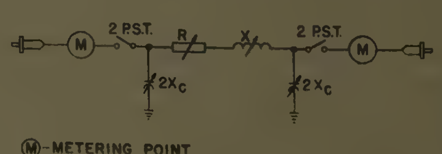
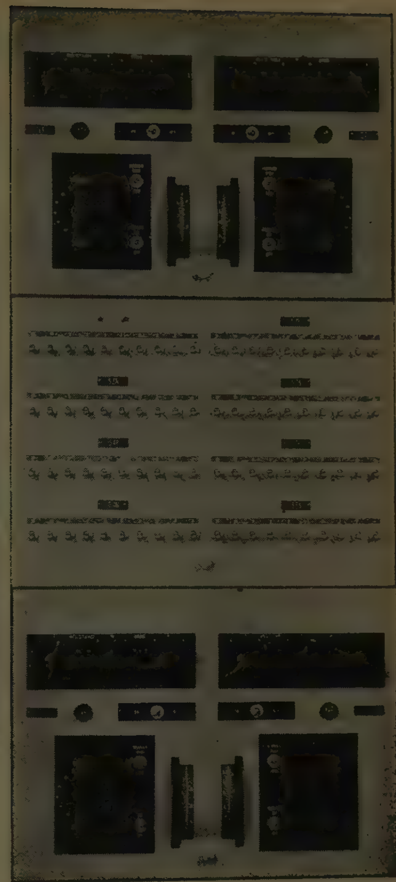


Figure 2. Single-line diagram of the connections of one pi-line unit



igure 3. (A, left) A-C network calculator showing the use of four instruments per generator, load voltmeters, and recording table. (B, right) Four pi-line units

uits, one-half of the charging capacity of all lines terminatng on a given bus is lumped into a single capacitor conected to the representative bus. This necessitated a corection in each line branch meter reading for that portion f its charging kilovolt-amperes lumped on the bus.

All data from modern calculating boards are now reorded directly in power system quantities on 1-line diarams of the system. All constants of multiplication have een included in the instrument scales. In order to faciliate the recording of these data on large system diagrams, pecial recording tables have been devised.

The recording table shown in Figure 3*A* has several nique features. The plastic recording surface has 5,486 ransparent spots on a field of black, so patterned as to atch the vertical and horizontal lines of a system 1-line diaram placed thereon within 1/8 and 3/16 inch, respectively. hese positions will conform to any reasonable system diaram without necessity of special ruling. The 370 lamp lugs, one for each of the 356 metered board circuit elements, four for positioning the diagrams on the surface, nd ten as spares, are connected to flexible cords which re counterbalanced by weights and pulleys, and which the nonused position rest on a designation panel located eneath the recording surface. The recording-surface lastic sheet is mounted over an aluminum plate which is erforated with holes concentric with the 5,486 transparent pots of the plastic sheet. With the top assembly elevated the vertical position, the lamp plugs, representing certain lements of the power system, are plugged into hole posiions corresponding to the desired circuit metering points n the system diagram. Then with the top lowered to the riting position, the selection of any board element for etering also illuminates the proper spot for recording the metered data on the system diagram. A separate selector assembly, operating in parallel with the master desk selector, is used for annunciating the selected circuit lamp. The use of this selector reduces the number of interconnecting leads to the recording table from approximately 400 to less than 40.

The use of generator reactance behind generator terminals in load flow studies permits approximate self-regulation of board generator outputs.

The representation of power transformers has been practiced by the Westinghouse Corporation since 1947 without any confusion among engineers using the board.

The addition of varmeters to the complement of generator instruments and the addition of voltmeters to the load impedances have given the board operators direct supervision of all generators and loads.

The use of pi-line circuits to represent high-voltage transmission lines with distributed capacitance permits true power values to be read at the line terminals.

The recording of system data directly on system 1-line diagrams has been speeded by using special recording tables.

REFERENCES

1. Total and Incremental Losses in Power Transmission Network, **J. B. Ward, J. R. Eaton, H. W. Hale.** AIEE *Transactions*, volume 69, 1950 (*Proceedings* T097).

2. Co-ordination of Fuel Cost and Transmission Loss by Use of the Network Analyzer to Determine Plant Loading Schedules, **E. E. George, H. W. Page, J. B. Ward.** AIEE *Transactions*, volume 68, 1949, pages 1152–60.

3. An Improved A-C Network Analyzer, **W. A. Morgan, F. S. Rothe, J. J. Winsness.** AIEE *Transactions*, volume 68, 1950, pages 891–5.

4. Use of A-C Network Calculator in Planning and Operating Electric Power Systems, **P. O. Bobo, H. A. Travers, E. E. George.** International Conference on Large High-Voltage Electric Systems (Paris, France), *Report 328.*

5. Auxiliary Equipment Facilities Network Calculator Operation, **L. B. Les Vesconte.** *Electric Light and Power* (Chicago, Ill.), volume 24, October 1946, page 50.

Expansion of the Southern California Edison System

A. A. KRONEBERG
FELLOW AIEE

FROM ITS BEGINNING in 1893, the Southern California Edison Company has grown to a 1,750,000-kw capacity system. This expansion is the direct result of population growth in southern California. Population approximately doubled during each decade except during that from 1930 to 1940. This rapid growth of population is due to immigration and was but temporarily retarded by the depression of the 1930's. Energy use and demand in the service area of the company are growing at an even faster rate due to increasing use of electric power per capita.

Two alternatives are available to the company in providing generating capacity for supplying this rapidly growing load. One is the continued development of the upper San Joaquin River which is known as Big Creek, and the other is the construction of steam-electric plants at the load. The additions of generating capacity to the company's system since 1945 include gains in capacity of old generating units resulting from change of system frequency from 50 to 60 cycles per second, the addition of a 35,000-kw unit at Big Creek Number 3, the addition of Redondo steam plant with 280,000-kw capacity, and the construction of Big Creek Number 4, now under way, which is expected to add 84,000-kw to the system capacity in 1951. For planning purposes, the installed capacity must be discounted by: hydroelectric capacity rendered idle by deficiency of river flow; hydroelectric capacity rendered idle because of shortage of water in storage reservoirs; generating capacity removed from service for maintenance and repairs; and a prudent reserve. The remaining capacity is the "dry year" capacity of the system and must be expanded to remain equal to the expected maximum demand of the load.

Figure 1. Map of the Southern California Edison Company's transmission system showing existing plants and lines, authorized plants and lines under construction, the 220-kv line of the Metropolitan Water District of Southern California, and the service area of the company

The transmission system of the company is an interconnection of 220-kv transmission lines linking the Big Creek hydroelectric plants, the Hoover powerhouse of the United States Bureau of Reclamation, and the steam plants. This transmission system evolved from the two parallel 150-kv transmission lines constructed in 1913 for transmitting Big Creek power to a 66-kv grid of lines and substations in southern California. The voltage of these lines was changed to 220 kv in 1923. With the growth of the system, the duty on 66-kv oil circuit breakers exceeded their interrupting capacity. This led to the adoption in 1928 of the fundamental principle underlying the planning of the system and its operation. This principle is the establishment of a "backbone" transmission system from which a number of subtransmission systems are supplied through 220/66-kv transformer banks. Except for having only the 220-kv system as a common source of supply, each one of these subtransmission systems is independent of the other. The term distribution in its broader meaning includes subtransmission systems, transformers, and distribution lines. Each of the groups of system equipment must be expanded at approximately the same rate as the expected growth of load to maintain the established standards of service.

When power is transmitted through the inductive circuits of a power system, there is created a demand for reactive power which is similar to the real power losses in the system. This demand is composed in part of magnetizing current taken by ironclad machines and in part of the I^2X losses in series impedances. The chief source of generation of reactive power on the company's system is synchronous condensers operating on 66-kv busses of major substations. A postwar deficit of 200,000 reactive kilovolt-amperes existed because no additions could be made during the war. The company has overcome the postwar deficit in reactive generating capacity, has kept pace with the growth of the reactive demand, and has provided for the growth of reactive demand during the next two or three years.

The problems of relay protection and system operation are not a planning engineer's responsibility. However, the system he has planned must be operable and protectable. For this reason the planning of the system of the Southern California Edison Company has always stressed simplicity. A simple system is easy to operate, it is easy to protect, and in the long run, it is easy to expand.

Digest of paper 50-138, "Expansion of the System of the Southern California Edison Company," recommended by the AIEE Committee on System Engineering and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

A. A. Kroneberg is with the Southern California Edison Company, Los Angeles, Calif.

Ignitron Converters for High-Energy Accelerators

J. L. BOYER
ASSOCIATE AIEE

C. R. MARCUM
ASSOCIATE AIEE

A LARGE proton-synchrotron (bevatron) requires the magnet current to build up rather slowly to a maximum value. To save the energy stored in the magnetic field and restart the cycle in a short time, the magnet current must be forced to zero by a counter voltage. The acceleration of particles is accomplished in the current build-up period, and this is the most critical portion of the load cycle.

The need for larger magnet power supplies resulted in a new application for power conversion equipment. The magnet power supply utilizes rectifier equipment which can either supply power or return power to a flywheel motor-generator set.

Two magnet power supplies have been manufactured. Equipment for the Brookhaven National Laboratory has a peak kilowatt rating of 30,000 kw with a pulse rate of 12 per minute. Equipment for the University of California Radiation Laboratory is rated 100,000 kw peak with a pulse rate of approximately ten per minute.

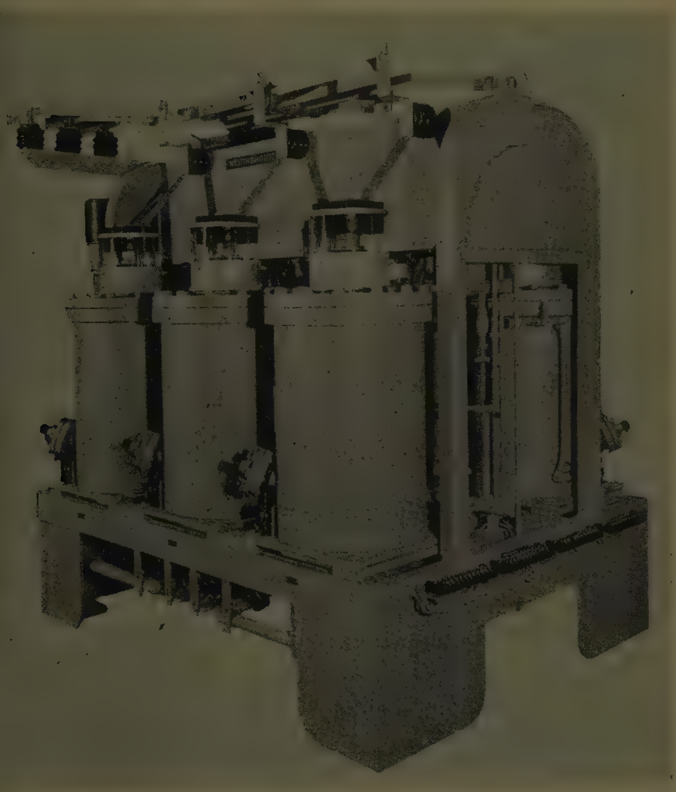


Figure 1. High-voltage ignitron rectifier assembly. Eight such assemblies have a peak power output of 100,000 kw

The selection of the type of rectifier was based on the requirements for high voltage and heavy direct currents with both rectification and inversion duty. Pumped-type ignitrons were used since they have a higher ratio of peak to average current, will withstand rough treatment, and have a long life. A typical 6-tube unit is shown in Figure 1.

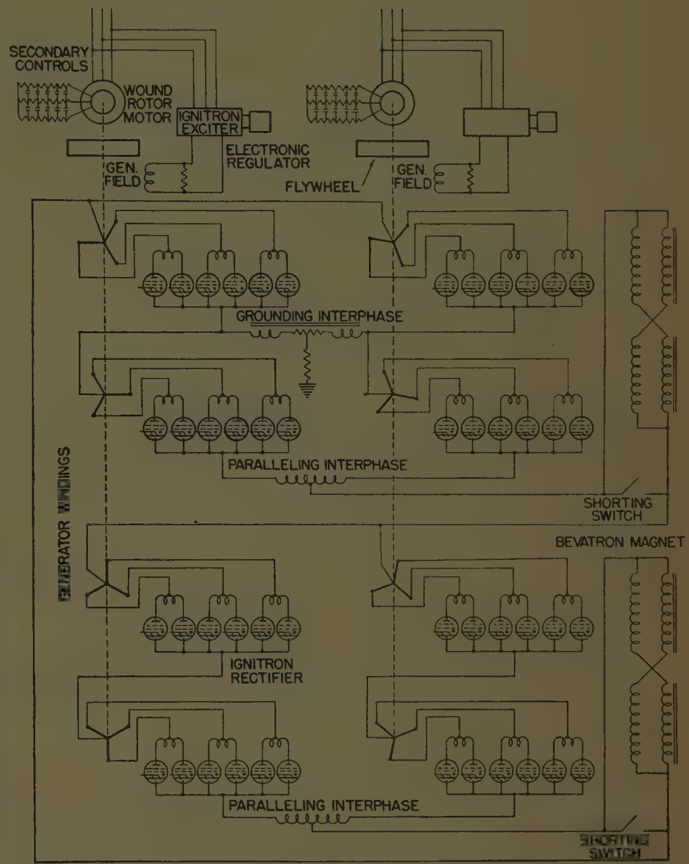


Figure 2. Power circuit of the magnet power supply for the University of California bevatron

Since a rather high direct voltage was desired for the magnet power supply, rectifier units will be operated in series. Figure 2 shows the complete power circuit for the University of California installation. Two identical units are operated in parallel to give the desired rating. Each generator Y supplies six ignitron tubes through balance coils. The generator Y's are displaced resulting in a 12-phase ripple in the magnet voltage. Energy storage in the flywheel on the motor-generator sets was required so that the disturbance on the power system would be within the required limits.

These magnet power supplies are the first of this type and are quite large. From experience obtained in designing these units, it is known that even larger units can be designed without serious complications.

Digest of paper 50-174, "Ignitron Converters for High-Energy Particle Accelerators," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

J. L. Boyer and **C. R. Marcum** are both with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

Structure and Polarization of Atoms and Molecules

J. C. SLATER

The total dipole moment per unit volume, or polarization, of a material greatly influences its dielectric constant. This article describes the action of dipoles in a dielectric by means of various simple models.

IN ORDER TO CONSIDER dielectrics from a molecular point of view, it is necessary to explain the actions of dipoles, which are produced throughout the interior of the dielectric.* A dipole is a combination of a positive and negative charge located a short distance apart, as shown in Figure 1. A dipole is characterized by a dipole moment, which is the product of the magnitude of the charge (positive at one end and negative at the other) and the distance between the charges. The electric field at a distance from the dipole resembles the magnetic field of a bar magnet and depends only on the dipole moment, not on the charge or separation independently.

With a material having a total dipole moment per unit volume **P**, called the polarization, the dielectric constant κ of the material is given by

$$\kappa = 1 + \mathbf{P}/\epsilon_0\mathbf{E}$$

where **E** is the electric field and ϵ_0 is the permittivity of free space (using the rationalized mks system of units). **P** is the vector sum of all individual polarizations in the volume, each being represented by a vector in the direction of the dipole and each with a magnitude which is equal to the dipole moment.

For κ to be a real constant, independent of field strength, **P** must be proportional to **E**. The mechanism by which the dipoles lead to the dielectric effect is well known, and is illustrated in Figure 2. Here each dipole is replaced by a cube of polarized material and all the polarization charges in the interior of the dielectric cancel, leaving only a surface charge adjacent to the capacitor plates producing the field. The surface charge is of opposite sign to the polarization charges producing it. The electric field in the capacitor is produced by the total charge, both that on the capacitor plates and that appearing by polarization. Since the polarization charge partially cancels the charge on the plates, the net field produced in a dielectric by a given charge on the capacitor is much smaller than if the dielectric were replaced by free space. If a dielectric is present, it requires much greater charge to produce a given voltage between the plates and this explains the increased capacity of the capacitor or the increased dielectric constant.

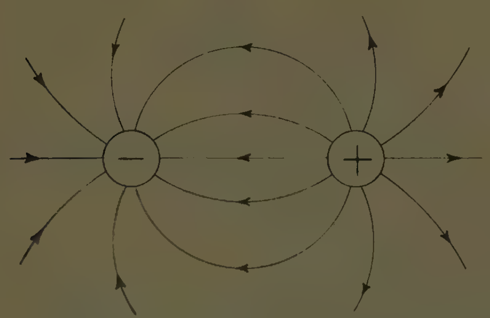


Figure 1. Lines of force for a dipole, which is a combination of a positive and negative charge located a short distance a part

There are a number of possible means by which dipoles might appear in the interior of the dielectric, depending upon the type of dielectric under consideration. Before looking into the molecular origin of the dipoles, it is worth while considering several simple mechanical models which lead to a similar effect and which help in understanding the situation actually present.

The simplest mechanical model is the linear oscillator. A particle of mass m and charge e is held to a position of equilibrium by a force which tends to pull it back to that position if it is displaced. This force is proportional to the displacement. If there is an external electric field acting on the charge, it will be pulled in the direction of the field, out to such a distance that the restoring force is equal and opposite to the force arising from the external field. The displacement will be proportional to the external field, and, therefore, the restoring force is proportional to the displacement.

If there is a fixed charge equal to $-e$ held rigidly to the initial position of the charge $+e$ so that it cannot be displaced at all by the external field, then the net result of the field will be to displace the two charges to a distance of separation proportional to the field. This action will result in the creation of a dipole proportional to the field.

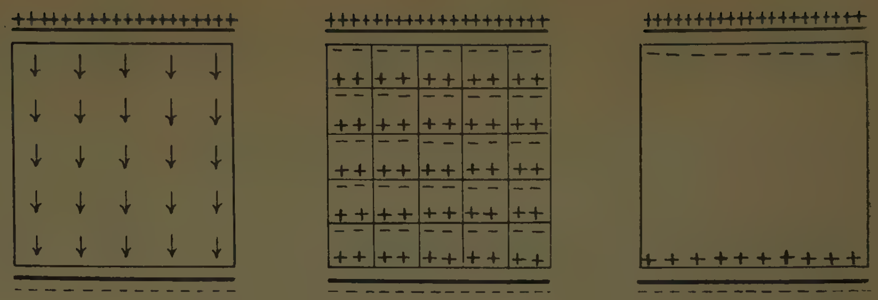
This simple model of the creation of dipoles by the action of an external field is a good basis for the understanding of dielectrics. Much of the classical theory of dielectrics is based on the premise that the dielectric contains a certain number of such polarizable particles per unit volume. In order to investigate the dielectric constant it is necessary

Essentially full text of a conference paper presented at a Symposium on Dielectrics held during the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. The symposium was sponsored jointly by the AIEE and the American Physical Society.

J. C. Slater is with the Massachusetts Institute of Technology, Cambridge, Mass.

* Second in a series of articles on dielectrics. The first was "Dielectrics in Electrical Engineering," A. von Hippel (*EE, Aug '50, pp 771–3*).

igure 2. A polarized dielectric between harged capacitor plates. Left, dielectric relaced by dipoles. Center, each dipole relaced by a polarized cube. Right, internal harges cancel each other to leave only polarization charges



o know only two parameters; the number of such dipoles er unit volume and the polarizability of each, or the number f dipoles per unit volume and the dipole moment which he dielectric acquires per unit applied field.

The linear-oscillator model can be used to illustrate urther the creation of dipoles by the action of an external ield if an a-c field is used instead of a d-c field. In this nstance a resonance effect is encountered. The particle, f definite mass and restoring force, has a definite resonant requency of oscillation, just as in the case of a pendulum or imple inductance-capacitance circuit. If the external ield has a frequency small compared to the resonant requency of the particle, then the polarizability will ot be dependent, to any great extent, on frequency. However, as the frequency of the external field is increased oward the resonant frequency of the particle, the polarizability increases without limit. The polarizability becomes nfinite at resonance and then negatively infinite, remaining egative as the frequency of the field approaches infinity ut decreasing in magnitude toward zero. This situation s altered if there is any friction acting on the oscillator, nalogous to the presence of resistance in a resonant circuit. With friction present, the polarizability will not become nfinite but will behave as shown in Figure 3, where the ielectric constant resulting from the presence of such scillators is shown. At the same time, absorption of nergy will occur, increasing to a sharp peak at the resonant requency.

If frequencies far above resonance are considered, the ielectric constant falls slightly below unity and gradually pproaches unity at infinite frequencies. A study of the frequency dependence of dielectric effects can be of great mportance in understanding the way in which a dielectric cts.

By knowing where resonance occurs, a great deal can be deduced about the type of particle being displaced. For instance, if it is not known whether the particle being displaced is an electron or ion, investigation of the resonant frequency will determine which it is. If the particle is an electron, with its small mass, the resonant frequency will be much higher than if the particle is an ion, with a relatively large mass.

Another simple model which gives some valuable information is a perfectly conducting sphere. If such a sphere is placed in an external field, induced charges will appear on its surface, as shown in Figure 4. The field of such a polarized sphere, at external points, is shown by elementary electrostatics to be the same as that produced by a dipole at the center of the sphere. The polarizability of the sphere can be found easily from electrostatics and is proportional to the volume of the sphere. If a dielectric is considered as consisting of many polarized spheres suspended in empty space, it would have a definite dielectric constant. Knowing the constant of proportionality between the polarization and the field, the dielectric constant can be determined from the following expression:

$$\kappa = 1 + \frac{3 \times \text{volume of one sphere}}{\text{volume of dielectric containing one sphere}}$$

The frequency dependence of this dielectric is not as simple as the case of the linear oscillator, as the conducting spheres show a very broad resonance, rather than the sharp resonance characteristic of the oscillator.

A further model of quite a different sort is provided by a dipole of fixed dipole moment, but pivoted so that it can rotate in any direction in space. This model could be a rod of definite length with equal and opposite charges at its ends and the center of the rod fixed. This is similar to the magnetic analogue of a compass needle. In the absence of an external field the rod can point in any arbitrary direction, but in an external electric field it will rotate to point along the field. This action produces a net dipole moment which takes on a saturation value (occurring when all dipoles are parallel to each other) under action of an arbitrarily small field, and for this reason is not appropriate to serve as a model for ordinary dielectrics.

If this model is set up on a molecular scale and it is assumed that the dipoles are subject to temperature agitation and the energy of polarization of the dipole in the external field, then the behavior depends on the relative magnitude of thermal energy, which is proportional to the temperature. If the energy of polarization is small compared to the thermal energy, as it will be for small fields, then the thermal agitation will tend to make the dipole point equally in all directions. Each individual dipole

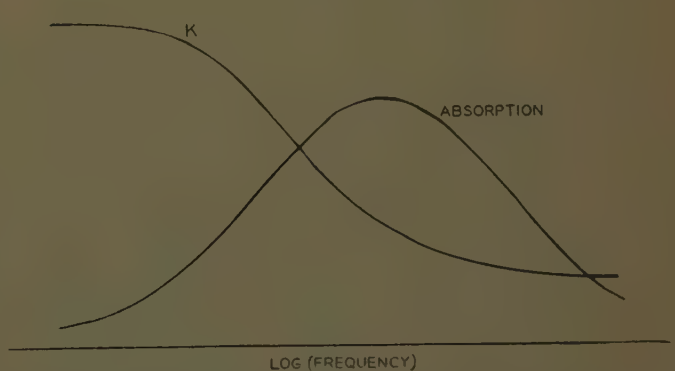


Figure 3. Dielectric constant and absorption as functions of frequency for a dielectric containing resonant dipoles

will spin around in some plane, similar to the action of a pinwheel, and will not tend to choose any specific direction of orientation.

In the presence of a field, however, the motions will be modified in such a way that the dipoles spend slightly more time pointing in the direction in which the field tries to orient them than in other directions. Consequently, there will be a net dipole moment set up, which for small fields is proportional to the field, and is also dependent on the temperature. This net moment per unit field, or polarizability, proves to be inversely proportional to the absolute temperature. The inverse proportionality shows that the dipole moment is very small at high temperatures, where temperature agitation interferes with orientation, but that as the temperature approaches absolute zero, an infinitesimal field is enough to produce complete orientation, which results in an infinite polarizability.

It is interesting to consider the effect of frequency on the polarization arising from orientation of permanent dipoles, with a-c fields applied. Calculations show that the dielectric constant and absorption as functions of frequency are as shown in Figure 5. The range of frequency over which the dielectric constant is falling from its low-frequency to its high-frequency value is quite large (several powers of ten), and absorption is strong all through this range. The transition frequency is not determined by any natural frequency of the system, for there is no characteristic resonant frequency, but it is related to what is called the relaxation time.

If the dipoles are oriented as they would be by a field and the field is suddenly removed, the question arises as to how long it would take the dipoles to revert to their steady-state distribution with no preferred orientation. The relaxation time proves to be proportional to the viscosity of the medium in which the dipoles are immersed. In a very viscous medium they are sluggish and take a longer time to reach equilibrium. The frequency range in which absorption occurs is in the neighborhood of the reciprocal of the relaxation time. Absorption can thus depend very strongly on temperature, since the viscosity of most fluids decreases greatly as the temperature increases.

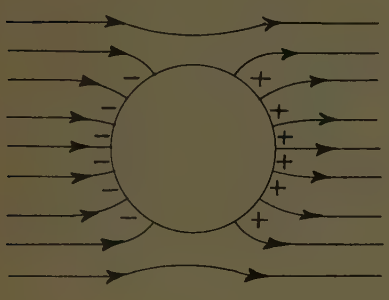


Figure 4. Lines of force around a polarized conducting sphere

In comparing the various simple models of polarization with what is actually found in the study of polarization of atoms and molecules, it is noted that any atom can be polarized by having its whole electronic structure displaced with respect to the nucleus. The polarizability arising in this way can be found in order of magnitude from the model of the conducting sphere, as the polarizability is roughly proportional to the volume of the atom or ion. This type of polarization is important in almost all dielectrics and, in some cases, forms the entire contribution to the dielectric constant. In other cases, however, there are additional forms of polarization which can be of the same order of magnitude or even larger. The large ions contribute the most to polarization of this type. The large ions are negative ions which have extra electrons contributing to their size, while the positive ions are smaller because they have lost electrons. In ordinary crystalline solids, as well as in solutions, polarization of this kind is well known. Often the greatest contributions come from the oxygen ions which, in such simple materials as sulphates, nitrates, and so forth, form the largest ions with the correspondingly largest polarizabilities.

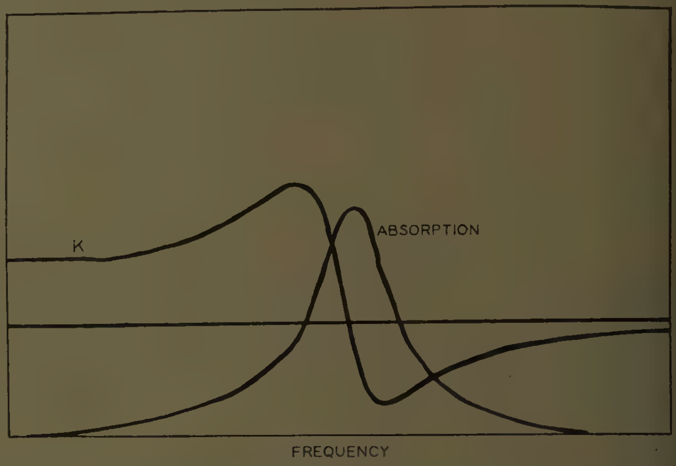
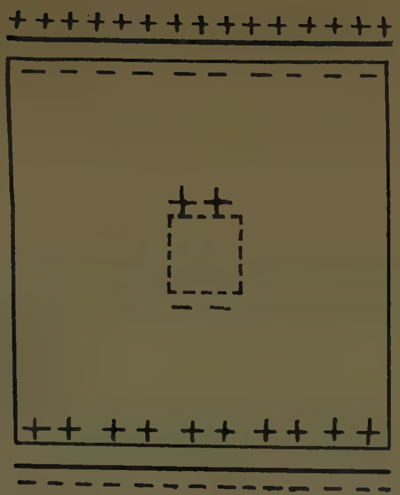


Figure 5. Dielectric constant and absorption as functions of frequency for a dielectric containing permanent dipoles subject to temperature agitation. Frequency is on a logarithmic scale

The natural resonant frequencies associated with electronic polarizations are found by the quantum theory to be just within the visible part of the spectrum, near the infrared and ultraviolet regions. Hence, the part of the dielectric constant associated with electronic polarization goes through an anomalous behavior, called anomalous dispersion, coupled with absorption. In this part of the spectrum and at much higher frequencies (as in the X-ray part of the spectrum), the dielectric constant is slightly less than unity. All through the part of the spectrum of interest to electrical problems, electronic polarization is practically independent of frequency.

A crystal, such as NaCl, composed of ions, has an additional type of polarization which can be as, or more, important than electronic polarization. This is a polarization in which all the positive ions (in this case Na^+) are displaced in one direction, and all the negative ions (in this case Cl^-) are displaced in the opposite direction. The restoring forces are the ordinary elastic forces holding the ions to their positions of equilibrium in the crystal. The resonant frequency associated with this type of polarization lies in the far infrared region, at a much lower frequency than that for the electronic polarization because of the greater mass of the ions. The resultant infrared absorption is closely con-

Figure 6. Dielectric of Figure 2 but with one polarized cube missing (as shown by the dotted outline), to show charges producing field acting on a dipole in the middle of the cube



nected with the phenomenon of residual rays. As a result of the polarization arising from ionic displacement, the dielectric constant of many solids in the visible part of the spectrum is much less than at low frequencies. However, even though resonance occurs in the infrared region, it is still at a high enough frequency so that it causes negligible change of dielectric constant with frequency in the ordinary electrical region of the spectrum.

Many molecules, such as HCl, have permanent dipole moments. In gases and liquids, where the molecules are free to rotate, they can set up an electronic polarization with the orientation of the dipoles opposed by temperature agitation. Such contributions by permanent dipole moments to the dielectric constant can be readily separated from contributions by other dipole moments by noting their dependence on temperature.

It has been stated that relaxation times depend on the viscosity of the medium, and that viscosity depends very strongly on temperature. Thus, relaxation spectra can occur in almost any part of the spectrum. Many of them are found in easily available frequency regions of short-wave or microwave oscillations and depend greatly on temperature. Often, the absorption at a fixed frequency, but with varying temperature, can show a peak at a given temperature. For instance, the very high dielectric constant of water at relatively low frequencies falls to more normal values when the frequency is in the centimeter range. These are the values which the dielectric constant normally has in the infrared and visible regions of the spectrum, with accompanying absorption.

The Clausius-Mosotti law has an important bearing on dielectric behavior. In Figure 2, which shows the action of dipoles arising from polarized cubes, it was not taken into account that in order to find the field acting on any given dipole to polarize it, the dipole cannot act on itself. Thus, to obtain the field acting on a dipole, the contribution of that dipole itself must be omitted, and the charges producing the field are actually as shown in Figure 6, where the polarization is omitted from one cube surrounding the dipole under consideration. The field in the center of such a cube (or alternatively in the center of a spherical hole) can be shown to be $\mathbf{E} + \mathbf{P}/3\epsilon_0$ rather than $\mathbf{E}$. When it is assumed that it is this field which polarizes the dipole rather than the simple field $\mathbf{E}$, the formula for dielectric constant becomes

$$\frac{\kappa-1}{\kappa+2}=\frac{\mathbf{P}}{3\epsilon_0\mathbf{E}}, \text{ or}$$

$$\kappa=1+\frac{\mathbf{P}/\epsilon_0\mathbf{E}}{1-\mathbf{P}/3\epsilon_0\mathbf{E}}$$

This formula, containing the correction factor $1-\mathbf{P}/3\epsilon_0\mathbf{E}$, differs from the earlier one only when the dielectric constant becomes significantly greater than unity, which is the case with the liquids and solids but not with gases.

The new formula leads to the possibility of the phenomenon of ferroelectricity. The correction term in the denominator is usually close to unity, as $\mathbf{P}/3\epsilon_0\mathbf{E}$ is considerably smaller than unity. However, there are many solids for which the term $\mathbf{P}/3\epsilon_0\mathbf{E}$ is equal to one-half or greater. It would take no change of magnitude in the polarization for $\mathbf{P}/3\epsilon_0\mathbf{E}$ to become practically equal to unity, but then the dielectric constant itself would approach infinity. This seems to be what actually occurs in a number of ferroelectric materials, of which barium titanate is an example. In barium titanate, that part of the polarization arising from ionic displacement is larger than usual and is large enough so that the dielectric constant does approach infinity. Furthermore, the polarization increases with decreasing temperature so that at a temperature in the convenient range the denominator goes to zero. The dielectric constant is observed to rise to infinity as this point is reached and below it the crystal acquires a permanent polarization.

New Speech Analysis Equipment

The Kay Electric Company of Pine Brook, N. J., has developed two new devices which should prove valuable as analyzers in phonetic studies, speech training, language instruction to the deaf, foreign language instruction to those with normal hearing, and the study of frequency shifts caused by the Doppler effect. The first device is known as the Sona-Stretcher, an instrument which lengthens the time scale of recorded sounds by a 2-to-1 ratio, but does not alter the frequency distribution. Thus, recorded speech when stretched seems to be spoken very slowly even though the pitch and quality of the voice are the same as before. The Sona-Stretcher covers a sound frequency range of about 100 to 5,000 cycles. The instrument consists of the stretching circuit and monitor amplifier, the turntable suitable for standard disk records, and the monitor loudspeaker. The second instrument, known as the Sonactor, is an audio-frequency analysis device intended as a fundamental voice pitch extractor. It covers that range of frequencies in which the fundamentals of the human voice are found, 100 to 600 cycles. The Sonactor produces a 3-dimensional oscilloscope display on which time is the horizontal axis, frequency is the vertical axis, and amplitude is indicated by brightness (Z axis). The frequency definition of the analyzer is 20 cycles.

Amplidyne-Controlled Log Carriage Drive

W. D. VINCENT
ASSOCIATE AIEE

HIGH PRODUCTION rates demanded by modern sawmills necessitate having a log carriage drive capable of moving the log-supporting carriage back and forth past the saw at an extremely rapid rate—in many mills this rate will be as high as 15 round trips per minute, when cutting a 16-foot log. For years the only prime mover which would meet these high production rates was steam, using the so-called "shotgun" drive or "twin-engine" drive. However, the recently developed amplidyne-controlled electric drive is now a serious competitor of the steam drive wherever high production, ease of control, and efficiency are demanded.

The amplidyne-controlled drive is designed to achieve optimum performance, utilizing the simplest possible combination of electric components. The entire drive consists of a carriage driving motor, a motor-generator set, an amplidyne control panel, an operator's master control lever, overtravel limit switches, and the required d-c motor starters. Figure 1 shows a simplified schematic layout illustrating the major drive components. A standard line of these drives has been developed, including ten different drive sizes, designed to meet the over-all drive requirements of all different types of sawmills. The drive is functionally quite simple, utilizing an adjustable-voltage type of system, with a d-c motor and a d-c generator. The amplidyne exciter furnishes excitation for the d-c generator and therefore controls the speed and direction of the driving motor. The amplidyne, although similar in appearance to a d-c exciter, is actually a d-c amplifier with very high amplification—more than 10,000 to 1—permitting the use of small control devices which are easy to manipulate. For the sawyer's operation, a simple heavy-duty drum-type master switch with a vertical handle is provided. By means of this master switch, the sawyer controls the direction and speed of carriage motion. Standing by the band saw and facing the carriage, the sawyer simply moves the master-switch handle forward to bring the carriage into the cut and throws the master-switch handle backward to return the carriage. When the master switch is in the "off" position, a portion of the amplidyne circuit insures positive, effective stopping of the carriage. If, for some unforeseen reason, the sawyer fails to stop the carriage before it reaches either end of the track, its motion will be arrested by the tripping of limit switches, which effectively take control of the carriage away from the sawyer's master switch and automatically bring it to a safe stop before the carriage goes through the building into the log pond. In addition, should there be an a-c power failure, the carriage drive will be brought to a safe stop without damage to any equipment. All stopping of the drive is done by regenerative braking; hence, high drive efficiency is provided by returning kinetic energy of motion to the electric power system.

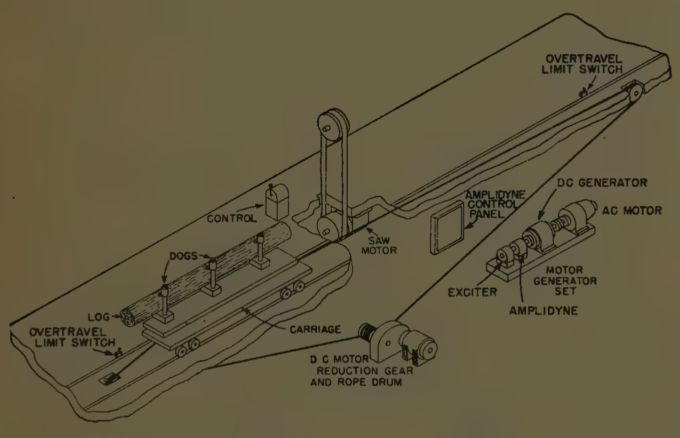


Figure 1. Simplified schematic layout showing the main components of the amplidyne-controlled electric log carriage drive

The carriage driving motor is the same sturdy motor used so successfully in steel mills for auxiliary and crane service and in surface mining for driving excavating shovels. Designed to carry high peak loads, this line of motors is exceptionally well suited for sawmill applications. The larger drive sizes utilize an identical unit to the motor for the generator, providing the same high peak-load capacity and simplifying the spare-parts problem.

The first amplidyne-controlled electric log carriage drive was installed in 1940. The application of the drive was necessarily slowed down during the war years, and subsequent drives were not installed until after the war. There are now installed and operating a total of 11 of these drives. In addition, six more complete drives are under construction for installation in the near future.

Summarizing, the advantages of the amplidyne-controlled electric log carriage drive are as follows:

1. High drive efficiency resulting in low operating cost.
2. Low maintenance expense.
3. Snappy acceleration and deceleration matching the performance of the steam shotgun.
4. Ease of operation, reducing operator fatigue.
5. Definite speed control during sawing, resulting in improved quality of output.
6. Improved safety of operating personnel—automatic overtravel protection with emergency stop.
7. Automatic emergency stop when a-c power is lost, preventing possible damage to the saw.
8. Smooth cable pull, resulting in long cable life.

Digest of paper **50-176**, "Amplidyne-Controlled Log Carriage Drive," recommended by the AIEE Committee on General Industry Applications and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

W. D. Vincent is with the General Electric Company, Schenectady, N. Y.

Design of Log-Scale D-C Meters

ALLEN STIMSON
ASSOCIATE AIEE

C. F. TAYLOR

IN MANY quantities, such as money, equal increments are of equal value regardless of the total amount. In other quantities, the increment is evaluated in relation to the total amount. Physical sensation is one example. According to the Weber-Fechner law, a stimulus which increases in geometric progression produces a sensation which increases in arithmetic progression. This means that the magnitude of the stimulus determines the importance of its increment. For instance, an increment of one foot-candle added to illumination of five foot-candles would noticeably increase visibility. Yet, one foot-candle added to 100 foot-candles would not be perceptible. The eye is equally sensitive to equal percentage differences. A light meter should, therefore, give an equal per cent of reading accuracy at each scale point. An instrument having this distribution has a logarithmic scale. Sound is evaluated on a logarithmic basis expressed in the familiar decibel units.

The mathematical background and the precepts involved in the design of log-scale d-c indicating instruments are presented here. These instruments are used to measure quantities that produce sensations increasing arithmetically for stimuli increasing geometrically.

In conventional d-c indicating instruments the scale distribution is linear. Each minor scale division represents an equal increment of current. In an instrument having logarithmic scale distribution, each minor scale division represents an equal percentage of the corresponding scale value.

Log-scale instruments are of value when the entire scale range is readable with the same accuracy as in an ammeter. For a voltmeter used on established circuits, the log scale would be of less usefulness because only values near the rated voltage would be read.

The advantages of the log-scale distribution may be summarized:

1. Equal per cent of reading accuracy throughout the scale range.
2. Better reading accuracies in the lower half of the scale.
3. Larger scale ranges are possible.
4. Higher deflection sensitivity near zero for the same full-scale rating.
5. The logarithmic scale can function as part of a slide rule with the instrument pointer performing the computation.

Log-scale instruments also have certain disadvantages which become obvious when they are compared to linear-scale instruments:

1. They are more expensive.
2. For equal full-scale rating the log-scale instruments require more power.
3. Unit increments near full scale are not so readable.
4. Variation in magnetic damping with scale deflection may make some dynamic characteristic harder to obtain for certain applications.

MATHEMATICAL BACKGROUND

AN ELECTRIC indicating instrument which provides equal reading accuracy at all scale points, expressed in per cent of the indicated value, must have a unique scale distribution.

The change in scale value readings per unit angle of pointer movement must be proportional to the scale value. If the scale is calibrated for signals x and the pointer deflection is θ, the following relationships are true:

$$\frac{dx}{d\theta}=\frac{x}{c_1} \tag{1}$$

$$d\theta=c_1\frac{dx}{x} \tag{2}$$

The solution of differential equation 2 is

$$\theta=c_1 \log x+c_2 \tag{3}$$

Equation 3 expresses the general scale law of log-scale instruments.

For the purpose of this discussion it is assumed that an

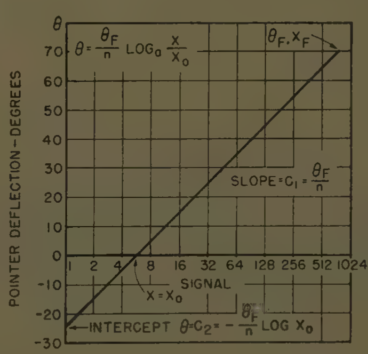


Figure 1 (above). The predetermined scale distribution

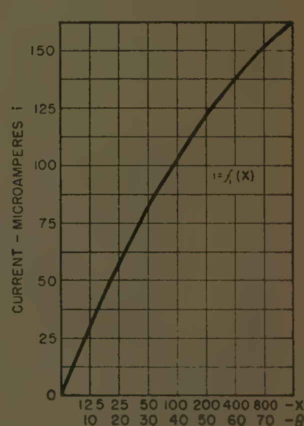


Figure 2 (right). The instrument current is related to the signal by this arbitrary function

Full text of paper 50-160, "Principles of Design of Log-Scale D-C Indicating Instruments," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

Allen Stimson and C. F. Taylor are with the General Electric Company, West Lynn, Mass.

instrument is to be designed having the predetermined scale values defined by equation 3 and shown in Figure 1. The scale has the following characteristics when the base of of the system of logarithms is a:

Scale range per log cycle $= a$

Number of log cycles in scale range $= n$

Scale range of instrument in log cycles $= a^n$

The scale range in terms of values of the signal x is $\frac{x_F}{x_0} = a^n$ (4)

The derivation of equation 3 defines the logarithm to the base ϵ. However, change to any base a merely changes the value of the constant c_1. The example, Figure 1, arbitrarily assumes the base a to be 2.

The values of the constants c_1 and c_2 may be determined from the boundary conditions:

$$\theta = 0 \text{ when } x = x_0 \tag{5}$$

$$\theta = \theta_F \text{ when } x = x_F \tag{6}$$

If limits 5 and 6 are substituted in equation 3 the constants are found to be

$$c_1 = \frac{\theta_F}{\log \frac{x_F}{x_0}} \tag{7}$$

$$c_2 = -\frac{\theta_F \log x_0}{\log \frac{x_F}{x_0}} \tag{8}$$

From equation 4 it is evident that

$$\log_a \frac{x_F}{x_0} = \log_a a^n = n \tag{9}$$

Equations 7 and 8 then become

$$c_1 = \frac{\theta_F}{n} \tag{10}$$

$$c_2 = -\frac{\theta_F}{n} \log x_0 \tag{11}$$

Constant c_1 is the pointer deflection per cycle and is also the slope of the curve of Figure 1. The constant c_2 is the value of θ when $x = 1$ and $\log x = 0$.

Equation 3 may now be written

$$\theta = \frac{\theta_F}{n} (\log_a x - \log x_0) \tag{12}$$

$$\theta = \frac{\theta_F}{n} \log_a \frac{x}{x_0} \tag{13}$$

Equation 13 expresses the general scale law for an instrument having logarithmic scale distribution. It states that equal increments of pointed deflection θ represent equal increments of log x.

In designing an instrument to track equation 13 it is assumed that the signal x is related to the instrument current i by a function

$$i = f_1(x) \tag{14}$$

and which may be an empirical relation of the type shown in Figure 2. In this figure values of both θ and x are shown according to the relation assumed in Figure 1. For any particular case the function

$$i = f_2(\theta) \tag{15}$$

is also known from Figure 1.

A d-c instrument at steady-state indication is subject to the electromagnetic deflecting torque

$$T_D = BSNi \tag{16}$$

From this well-known relation the flux density may be found. For a log-scale ammeter where the signal is i and the restoring torque is $K\theta$, the flux density from 13 and 16 is

$$B = \frac{T_R}{SNi} \tag{17}$$

$$= \frac{K}{SNi_0} \theta a^{-\frac{n}{\theta_F}\theta} \tag{18}$$

The graph of this equation is similar to that in Figure 4. For an actual instrument the nonlinear restoring torque, as shown in Figure 3, is the sum of several components arising from iron in the moving system to the torque supplied by the control springs:

$$T_R = T_S + T_P + T_M \tag{19}$$

The current i may also be nonlinearly related to the signal X as in equation 14. Values of B are calculated point by point from equation 17 using values of i computed from equations 13 and 14 and values of T_R from equation 19. Figure 4 shows the flux distribution for an actual design.

DESIGN OF THE MAGNETIC SYSTEM

The distribution of the effective flux density B along the path of the moving coil is one parameter which can be controlled. The method of design of the magnetic system will be illustrated by a general example.

The signal x to be measured is manifested by a current

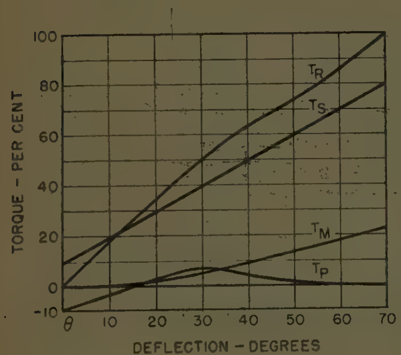
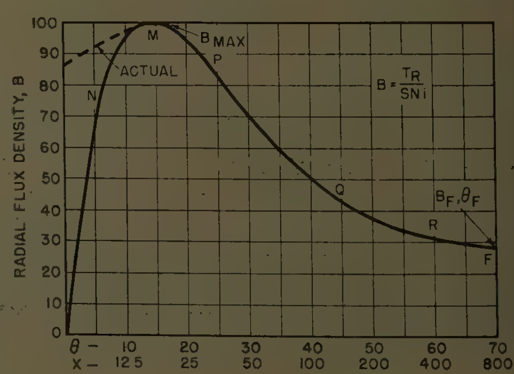


Figure 3 (left). The total restoring torque is the sum of the torques due to control springs, parasitic iron, and ferromagnetic controls

Figure 4 (right). The variation of flux density in the path of the moving coil has a unique pattern for log-scale instruments



having an arbitrary relation shown in Figure 2. Inasmuch as Figure 1 has shown the desired scale law relating and x, the corresponding values of θ are also shown as n abscissa in Figure 2.

The instrument mechanism selected for this application has a known torque S per ampere turn per kilogauss of B and a moving coil of N active turns. It is then easy to compute values of the product SNi from the data in Figure 2 for various values of θ.

The instrument mechanism selected may be assigned trial torque characteristics. These are illustrated in Figure 3 and consist of the control-spring torque T_S, the parasitic torque T_P due to distributed magnetic impurities in the moving system, and the other torques T_M due to a magnetic vane and possible polarized pivots. At each value of θ the summation of torques T_R has the unique value of equation 19 shown in Figure 3. The numerical values of these torques initially must be assumed for the purpose of evaluating the corresponding flux distribution.

The required distribution of the radial component of flux density B is calculated from equation 17 by dividing the values of T_R by the corresponding values of SNi for each value of θ. The resulting unique function of B is plotted in Figure 4.

This distribution of flux in the air gap, Figure 4, is based on assumed torques of Figure 3. The moving-iron torques T_P and T_M are dependent upon the flux distribution and, therefore, must be recomputed or measured for the actual flux distribution. The new values may demand a second computation of the required flux distribution.

CHARACTERISTICS OF THE FLUX DISTRIBUTION

THE DESIGN of a magnetic system which will provide the flux density distribution of Figure 4 is limited by several practical considerations.

The density cannot be zero at scale zero $\theta = 0$ because there will be a minimum stray field which cannot be avoided. Hence, the actual log-scale distribution must start at some small angle above scale zero. If B were zero at scale zero, initial deflection of the moving system could never result from any current i according to equation 16. The initial deflecting torque would be zero and the response time would be infinite.

The steepness of the gradient of the air-gap flux density $dB/d\theta$ between points P and Q in Figure 4 is limited by the actual length of the path of the moving coil and the value of B_{max}. The longer the path, the easier the density can be controlled.

The maximum range of the instrument is also limited by the minimum flux density P_F, which can be obtained at the full-scale position of the moving coil.

The higher the value of the maximum flux density B_{max}, the higher the sensitivity of the instrument and the greater the possible scale range. Instruments can be designed for values of B_{max} over 6,000 gausses, but the resulting high flux-density gradient increases the highly variable parasitic torques to an uncontrollable level.

The design of the air gap of a conventional expanded-scale moving-coil d-c instrument is shown in Figure 5. This construction can be made to fit part of the characteristic of Figure 4 but only for short scale angles and small ranges. High flux gradients cannot be obtained with this construction in conformance with the required distribution.

The sharp peak of flux density at B_{max}, Figure 4, indicates that the field magnet should have salient poles as at A in Figure 6. The steep gradient at N, Figure 4, suggests that the core be cut away as at G, Figure 6. To obtain the

Figure 5 (above). A conventional expanded-scale instrument

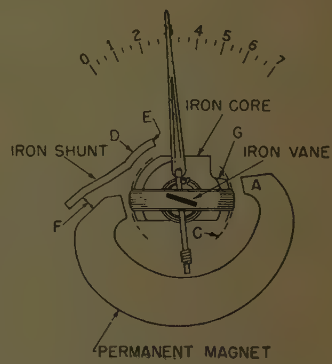


Figure 6 (right). The magnetic structure of a log-scale instrument

relatively low density B_F at full scale, both the core and the magnet are spaced away from the locus of the moving coil as at C, Figure 6. The density at C also may be controlled by reducing the depth of the core compared to that at G.

The point of maximum flux density, Figure 4, occurs at about 20 per cent scale deflection. To obtain maximum sensitivity the maximum density should be at zero scale position. Therefore, it is apparent that a logarithmic scale distribution gives maximum uniformity of reading accuracy at some sacrifice in sensitivity.

The instrument magnetic system shown in Figure 6 was designed for ten degrees deflection per log cycle with a log base of two. This means that the signal indication doubled every ten degrees on the scale. The range covered was approximately seven cycles or 128 to 1 within the limits of its logarithmic distribution.

To obtain log distribution of less than ten degrees per cycle would require proportionately higher flux-density gradient. This would be obtained by higher flux densities at the poles A within a smaller angular space and greater air gap at C. Soft iron poles would be helpful in concentrating the flux.

To obtain log distribution of more than ten degrees per log cycle, the pole faces A would be broadened and the air gaps at C reduced.

It is obvious that the distribution of flux density can be controlled by shaping either the core or magnet poles. Shaping the core has less influence than shaping the magnet poles. The effective flux density can also be controlled by change in the direction of the flux since only the radial component is effective.

The parasitic torques, due to magnetic impurities distributed throughout the moving system, are not noticeable in concentric gap instruments but do affect the scale dis-

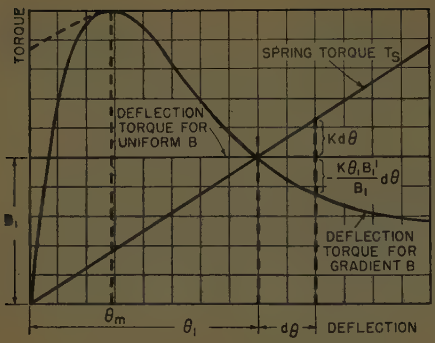


Figure 7. The negative gradient of flux density in a log-scale instrument increases the incremental restoring torque

tribution with magnetic systems having an effective flux-density gradient.

SCALE TRACKING ADJUSTMENT

There are several methods of reducing the deflecting torque of a permanent-magnet moving-coil d-c instrument to obtain the desired accuracy. One of the most convenient and widely used methods consists of demagnetizing the permanent magnet by application of an a-c field. This method is also quite satisfactory for log-scale instruments.

Demagnetization of a salient-pole magnet changes the restoring torque due to magnetic vanes or parasitic iron in the moving coil. This causes shift of the zero position of the moving coil by an amount which depends upon the per cent of reduction of field strength and the magnitude of these torques. The moving-iron torques are in equilibrium with the control springs at the initial rest position. Reduction of field strength reduces these torques also, and the coil moves to a new position of equilibrium. This zero shift is usually not over two or three degrees.

Adjustment by demagnetization must be done, therefore, in two or more steps. The zero position should be checked or reset after each adjustment. The pointer zero always shifts down scale in this type of instrument.

Log-scale instruments do not have the consistent distribution that uniform scale instruments have. Means for adjusting the distribution in one instrument are shown in Figure 6. The soft iron shunt D is pivoted at E and its effect is controlled by varying the air gap at F. This shunt is so located that it affects only the upper half of the scale.

The log-scale instrument, therefore, can be adjusted precisely at two scale points. The first adjustment is demagnetization at a point in the lower quarter of the scale. Second, the shunt is reduced in effectiveness by increasing the air gap F until a point in the upper quarter scale is correct.

DYNAMIC CHARACTERISTICS OF LOG-SCALE INSTRUMENTS

The magnetic damping and incremental restoring torque vary with pointer deflection in log-scale instruments, whereas they are constant in uniform-scale instruments. The difference is due to the variation in flux density illustrated in Figure 4 and Figure 7.

The motion of the moving system obeys the classical differential equation:

$$I\frac{d^2\theta}{dt^2}+D\frac{d\theta}{dt}+K\theta=T_D \tag{20}$$

The coefficient D is the familiar damping constant, and its numerical value is proportional to the square of the flux density B:

$$D=C_3B^2 \tag{21}$$

In this analysis the ferromagnetic torques are neglected to simplify the derivation. The magnitude of the restoring torque is the important consideration rather than its source.

Equation 20 is nonlinear because both D and T_D are functions of B, and B is a nonlinear function of θ.

For the purpose of analyzing small oscillations of the moving system the relation of B and θ shown in Figure 4 and Figure 7 may be represented by the following approximation of the expansion of B in powers of θ by Taylor's theorem:

$$B=B_1+(\theta-\theta_1)B_1' \tag{22}$$

where

$$B_1'=\left.\frac{dB}{d\theta}\right]_{\theta=\theta_1}$$

If it is further assumed that the velocity $d\theta/dt$ as well as the amplitude is small, then also negligible is the contribution of the variation of B^2 to the variation of the product $B^2(d\theta/dt)$. Therefore, it can be assumed that the value of B in the equation

$$D_1=C_3B^2 \tag{23}$$

does not vary with θ.

It is also seen from equations 16 and 22 that

$$SNi_1=\frac{K\theta_1}{B_1} \tag{24}$$

If equations 22, 23, 24, and 16 are combined with 20, then

$$I\frac{d^2\theta}{dt}+D_1\frac{d\theta}{dt}+\left(K-\frac{K\theta_1}{B_1}B_1'\right)\theta=C_4 \tag{25}$$

This is the familiar equation for damped harmonic motion. From the known solution of equation 25 the damped frequency of oscillation of the moving system is seen to be

$$f_d=\frac{1}{2\pi}\sqrt{\frac{K-K\theta_1B_1'}{I}-\frac{C_4^2}{4I^2}} \tag{26}$$

and the undamped frequency is

$$f_0=\frac{1}{2\pi}\sqrt{\frac{K}{I}} \tag{27}$$

For values of θ greater than θ_M, Figure 4 shows that $dB/d\theta$ = B′ is negative. Therefore, for the greater part of the scale

$$\frac{K-K\theta_1B_1'}{I}>\frac{K}{I} \tag{28}$$

This means that the damped frequency may be higher than the undamped frequency

$$f_d>f_0]_{\theta>\theta_M} \tag{29}$$

In one instrument of this type the damped frequency near full scale was found to be twice the undamped frequency.

The additional restoring torques which cause the higher lamped frequency are shown graphically in Figure 7. This additional torque also helps minimize the effect of bearing friction.

It is obvious from the form of equation 25 that the total restoring torque for small deflections $d\theta$ of the moving system energized with current i is

$$T=T_1+Kd\theta-\frac{K\theta_1 B_1'}{B_1}d\theta \qquad (30)$$

The ability of an instrument to overcome the effects of bearing friction is frequently judged in terms of the ratio T/W of torque T to weight W of the moving system. The ratio $T/W^{1.5}$ is also considered significant. These factor-of-merit concepts were developed for uniform-scale instruments. In instruments having a gradient of flux density the value of T is not the spring torque alone but has the additional term added to it as shown in equation 30. This total torque is shown in Figure 7 to provide a greater restoring torque for the instrument having a negative flux-density gradient.

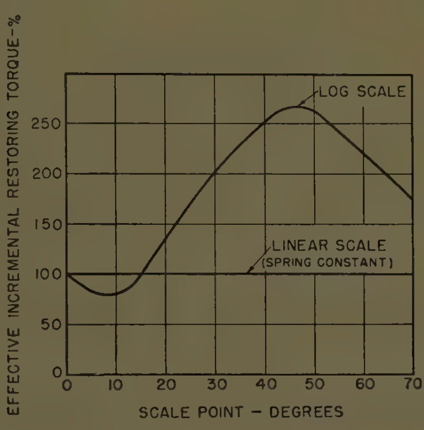


Figure 8. The effective factor of merits of a log-scale instrument is greater than indicated by (T/W)^1.5 and varies with scale deflection

The per cent improvement in effective restoring torque due to the flux gradient is shown graphically in Figure 8. Throughout most of the range the incremental restoring torque of the log-scale instrument is higher than that of the linear-scale instrument.

EXAMPLE OF LOG-SCALE INSTRUMENT

One embodiment of the design principles here outlined is the new exposure meter shown in Figure 9. Logarithmic scale distribution was desired so that the instrument scale could function as part of the slide rule for computing exposure from the light indication. Conventional instruments require the photographer to read the scale and then find this value on the slide-rule computer. In this new meter the log-scale distribution permitted synchronizing the instrument pointer deflection with the slide rule so that neither of these reading operations is needed. This improvement reduces the number of operations, time required, and chances for error to half of those of a conventional exposure meter.

For this particular instrument the signal x is the light to be measured. A typical photovoltaic cell converts this signal to current according to the curve in Figure 2.

These log-scale instruments have been manufactured by mass production techniques with no difficulties from scale distribution.

CONCLUSIONS

Instruments having logarithmic scale distribution provide equal (per cent) reading accuracy at all points and are especially useful where both high threshold sensitivity and large-scale range are desired in one device.

The magnetic system of a log-scale instrument can be designed on the basis of mathematical formulas, which are solved point by point, because the quantities involved cannot be represented by simple algebraic expressions. Initial assumptions of instrument characteristics are used to determine the corresponding ideal distribution of flux density. From the nearest practicable approach to this flux distribution, the corresponding instrument torques are recalculated and the design of the instrument is then adjusted accordingly.

Adjustment of scale distribution is usually required to obtain reasonable accuracy. One method of securing the distribution adjustment comprises a movable soft-iron magnetic shunt. Adjustment for accuracy of the lower quarter of the scale is obtained by demagnetization. Adjustment in the upper quarter of the scale is accomplished by shunting the flux. The mechanism tracks at mid-scale if the moving system is correctly oriented with respect to the salient magnet poles.

Figure 9. A log-scale instrument mechanism is used in this new exposure meter which uses the log scale as a part of a slide rule to be used for computing exposure

The damping is substantially higher at the lower end of the scale than at the high end. The conventional concept of the ratio of torque T to weight W or $T/W^{1.5}$, known as the factor of merit, is not indicative of the effects of possible bearing friction in a log-scale instrument except near the zero position. The gradient of flux density gives effectively higher restoring torques than the static factor of merit indicates and, therefore, greater freedom from bearing-friction errors.

The principles given here are applicable to general instru-

ment design. They have been illustrated by specific reference to a new exposure meter which has been manufactured in large quantities.

NOMENCLATURE

Symbol	Meaning	Units
a	Scale constant (log base)	
B	Radial component of magnetic flux density	gausses
B_1	Flux density B at angle θ_1	gausses
B_1'	Flux gradient $dB/d\theta$ at angle θ_1	gausses per radian
B_F	Flux density B at full scale	gausses
B_{max}	Maximum flux density at angle $\theta=M$	gausses
C_1	Scale constant (θ_F/n)	
C_2	Scale constant $[(-\theta_F/n)\log x_0]$	
C_3	Damping shell constant $=D/B^2$	$\frac{\text{dyne centimeter second}}{(\text{gauss})^2}$
C_4	Constant $=SNi_1(B_1-\theta_1 B_1')$	dyne centimeters
D	Damping constant	dyne centimeter seconds
D_1	Damping constant at angle θ_1	dyne centimeter seconds
f_0	Undamped frequency of oscillation	$(\text{seconds})^{-1}$
f_d	Damped frequency of oscillation	$(\text{seconds})^{-1}$
i	Current in moving coil	amperes
i_1	Current causing deflection θ_1	amperes
I	Moment of inertia of moving system	gram(centimeters)^2
K	Control spring constant	dyne centimeters per radian
n	Number of log cycles on scale	
N	Number of turns on moving coil	
S	Torque per ampere turn per kilogauss	
T	Torque (general)	dyne centimeters
T_D	Deflecting torque	dyne centimeters
T_M	Torque due to iron vane on moving system	dyne centimeters
T_P	Parasitic torque due to magnetic impurities in moving system	dyne centimeters
T_R	Total restoring torque	dyne centimeters
T_S	Torque due to control springs	dyne centimeters
T_1	T_S at θ_1	dyne centimeters
W	Weight of moving system	grams
x	Signal calibrated on instrument scale	
x_0	x at $\theta=\theta_0$	
x_F	x at $\theta=\theta_F$	
θ	Scale angle	radians
θ_F	Full scale angle	radians
θ_M	Angle at maximum flux B_M	radians

Survey of Bushing-Type Current Transformers for Metering Purposes

G. CAMILLI
FELLOW AIEE

The great simplicity, reliability, and low cost of the bushing-type current transformer has led to various schemes to improve its accuracy to metering standards. This article reviews these schemes, which culminated in the orthomagnetic bushing-type current transformer.

THE BUSHING-TYPE current transformer is a device with exceptional simplicity, convenience, reliability, adaptability to the highest voltages, and economy, and yet it has been disappointing in the first requirement of accuracy: accuracy as to the ratio and phase angle of the indicated current, especially to the smaller line currents. For line currents under 1,000 amperes its accuracy diminishes with diminishing current.

Operating at a reasonable flux density a transformer requires a certain number of exciting ampere turns so that the more the turns the less the current will be. As the bushing-type current transformer, built around the bushing conductor as its primary, has only one turn its exciting current has to be larger than that for units with many turns. In addition, the exciting current varies nonlinearly with the load and thus resists simple corrective measures, such as compensation by modification of the turns ratio. Since current transformers are operated at low densities the deviation of the excitation curve from a straight line is not due to saturation but to the increase in permeability with increasing density around the lower bend of the magnetization curve (Figure 1). The results of this nonlinearity are almost as objectional as those of saturation with the difference that the errors are larger at the smaller loads instead of at the higher loads.

The various schemes which have been proposed or used to overcome these difficulties can be grouped under the following classifications:

1. Direct reduction of the exciting current.

Essential text of paper 50-63, "A Survey of Bushing-Type Current Transformers for Metering Purposes," recommended by the AIEE Committees on Instruments and Measurements and Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

G. Camilli is with the General Electric Company, Pittsfield, Mass.

2. Two-stage transformation. Without modification of the exciting current, an attempt is made to modify the secondary current by a quantity equal to the exciting current.

3. Rotation of the exciting-current vector. The phase angle is reduced by producing a rotation of the exciting current vector, and subsequently the ratio error is modified by other schemes.

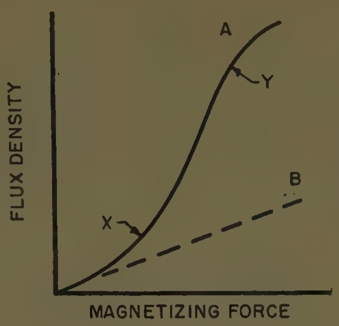


Figure 1. Characteristic shape of magnetization curve for iron. X is the region of increasing permeability, and Y is the threshold of saturation

4. Straightening the exciting-current curve.

5. Straightening of the exciting-current curve and simultaneous reduction of the exciting current.

Direct Reduction of Exciting Current. Current transformers are operated at very low flux densities (100 to 5,000 lines per square inch), and therefore, in order to reduce the exciting current, a material having low losses and high permeability is desired. Such materials are available (Nicaloi, Hypernik, Permalloy, and Numetal). The cost of these materials is several times that of ordinary steel, their saturation densities are low, and in general they have very poor resistance to mechanical shocks. With such materials it is possible to obtain bushing-type current transformers having fairly good accuracy at a rated primary current, 500 amperes and higher. For lower currents more complicated schemes must be used.

If a current transformer could be operated with a low alternating flux density but at the highest permeability of the iron, then some real benefit could be gained. Premagnetization of the core of the current transformer can be derived from an auxiliary core, or much more simply and directly from the secondary current of the current transformer, as in the scheme shown in Figure 2. The flux in each core is due to the resultant flux of the primary and secondary ampere turns. By the proper selection of the number of turns in the secondary turns on the two cores comprising the transformer, on core 1 the ampere turns of the primary can be made to exceed those of the secondary, while on core 2 the secondary ampere turns can be made to exceed those of the primary. As a result the flux density in the two cores is increased in the region of maximum permeability.

Two-Stage Transformers. Figure 3 illustrates diagrammatically the conventional 2-stage current transformer and a 2-stage wattmeter or watt-hour meter. P_1S_1 is the first stage of the current transformer feeding the first-stage current coil C_1 of the meter. The current in C_1 differs (vectorially) from the correct secondary current by the exciting current in P_1. The second-stage transformation aims to put into C_2 a current equal to this difference. In the second stage of this current transformer P_2' and P_2'' act jointly as the primary; that is, the net resultant ampere turns of P_2' and P_2'' act as the primary ampere turns inducing a corresponding secondary current in S_2 which flows in the second-stage current coil C_2 of the meter. The net ampere turns of P_2' and P_2'' are the exciting ampere turns of the first stage, and thus the current delivered to S_2 and C_2 represents and makes up for the exciting-

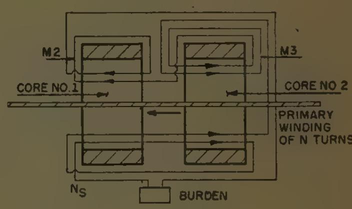


Figure 2. Schematic diagram of a current transformer with auxiliary excitation derived from the secondary side of the current transformer

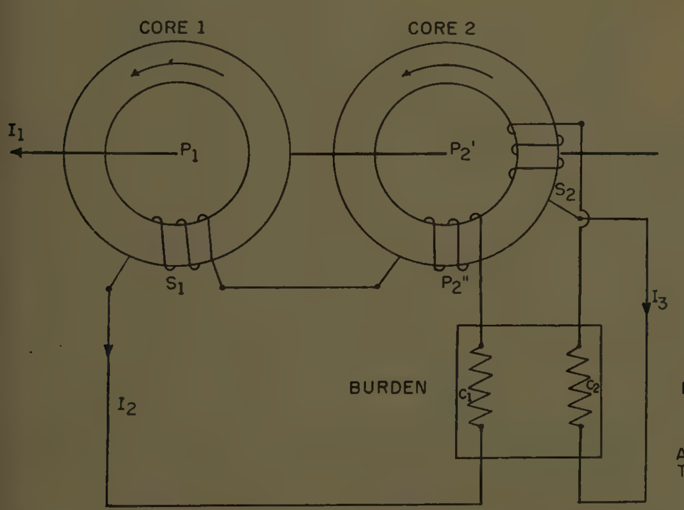


Figure 3. Diagram of the conventional 2-stage current transformer and a 2-stage wattmeter or watt-hour meter

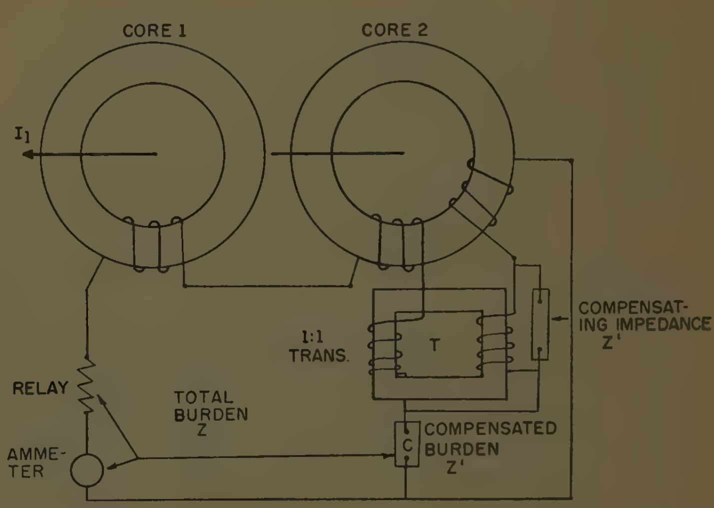


Figure 4. Scheme for using single-element meter with 2-stage transformer which eliminates the use of special instruments

current error of the first stage. In transforming the exciting current of the first stage, the second-stage current transformer requires an exciting current so that the exciting-current correction by the second stage is not exactly 100 per cent.

In order that the two stages may perform without interference from each other, it is necessary that the two circuits have no appreciable net mutual impedance.

In the original Brooks and Holtz current transformer the two current coils C_1 and C_2 are separate from each other, and each one is provided with a separate potential coil with which to react. The disadvantage of the original scheme of requiring special instruments can be obviated by the arrangement shown in Figure 4. The impedance Z is substantially equal to the impedance C times the ratio of transformer T. The net mutual impedance between the first and second stage is the impedance of the coil C, and the transformer T accomplishes the desired reversal of sign so that one can neutralize the other. The addition of the dummy burden Z results in a total burden which is approximately twice that used with a simple 2-stage metering transformer, and the errors are somewhat larger.

Rotation of the Exciting-Current Vector. One of the schemes that is based on the principle described in the preceding paragraph is shown diagrammatically in Figure 5. A small auxiliary core operated at a relatively high flux density energizes the main core. Since the main core and its secondary burden may be regarded as an inductive load on the auxiliary winding n_3', the current I_3 has a

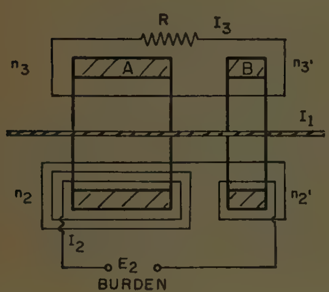


Figure 5. Wellings and Mayo current transformer. The small auxiliary core operated at relatively high flux densities energizes the main core

considerable phase angle with respect to I_1, the magnitude and phase angle being regulated by the resistor R. The resultant ampere turns on the main core are the sum of I_1 and n_3I_3. The net result is a reduction in phase angle and increase in ratio of the main transformer. A few turns of the secondary are wound on the auxiliary core to compensate for the ratio error. This scheme gives reasonably good results when the rated current is not lower than 600 amperes.

Straightening the Exciting-Current Curve. If the exciting current could be made linearly proportional to primary current, both phase-angle and ratio errors would be constant. Once made constant their magnitude can be reduced by several schemes. A general principle which has been used is to balance increasing and decreasing permeability against each other. A scheme which is being used with good results is shown in Figure 6. In this scheme a special reactor working at different degrees of saturation is connected across the burden. The constant errors are then compensated by the addition of capacitors and resistance as shown in the diagram.

Fairly good accuracies have been obtained with this

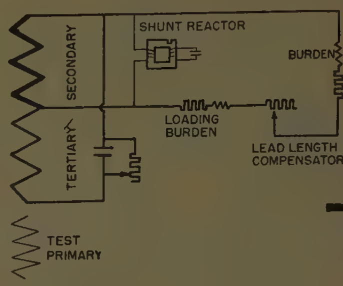


Figure 6 (above). Connection diagram of current-transformer compensating scheme

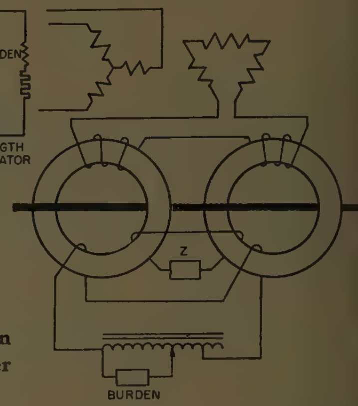


Figure 7 (right). Diagram of connection of a bushing-type current transformer with auxiliary triple-frequency excitation to compensate for phase-angle error and ratio error

scheme at a primary current as low as 300 amperes. The transformer is adjusted to operate at a constant secondary burden.

Straightening of the Exciting-Current Curve and Reducing the Exciting Current. The ortho-magnetic current transformers incorporate the following principle.

If a core is excited from an a-c source and then a higher frequency exciting current superimposed on it through a separate winding, it will be observed that the volt-ampere input by the original (lower frequency) circuit is diminished by the superimposition. To the lower frequency source, the iron behaves as if it were an improved material. Also it will be observed that from the low-frequency side the exciting current is proportional to the core density.

When this principle is applied to the bushing-type current transformer the ratio errors are divided by more than ten and phase angle by more than 60.

With the errors rendered constant the phase-angle error is compensated by an auxiliary impedance Z, and the ratio error by a tapped autotransformer between the secondary and the burden (Figure 7).

Table I gives the results obtained on an ortho-magnetic bushing-type current transformer for a 161-kv circuit.

Table I. 161-Kv Bushing-Type Current Transformer
Ratio: 150/5; Burden: 15 Volt-Amperes at 0.9 Power Factor

Secondary Current, Amperes	Ratio Correction Factor	Phase Angle, Minutes
0.5	1.0056	+4
1.0	1.0050	+3
2.0	1.0047	+2
3.0	1.0045	+1
5.0	1.0043	0

Selection and Application of Power Transformers

H. P. SEELYE
FELLOW AIEE

THE CHOICE of a power transformer is governed largely by the characteristics of the system, the precedents set by previous purchases, and the established standards of the industry. Any discussion of the selection of transformers must deal to a considerable extent with standards. Several important features of power transformers, with particular attention paid to the relation between the needs of the operating system and the standardization activities now in progress, will be discussed here.

Power transformers have been standardized to a considerable degree for many years. Recently, however, there has been a strongly directed effort toward the revision and extension of these standards by the Joint Edison Electric Institute–National Electrical Manufacturers Association Committee on Preferred Voltage Ratings for A-C Systems and Equipment and the American Standards Association Subcommittee on Standardization of Power and Distribution Transformers.

The major problem for those who are setting up standards is to determine those items and details which will best fulfill the wishes and the real needs of the greatest majority. The problem of the user is first to participate in the formulation of the standards to the extent of having his ideas and practices fully considered, and thereafter to find means, if possible, for adopting the established standards for his own purposes and thereby join the majority in getting the price savings which should result.

The chief purpose of standardization is, of course, reduction in cost. This is accomplished mostly by a reduction of varieties and a concentration on the most advantageous types. The increased volume of these types allows economies in production, distribution, and stocking. To realize this objective, standards adopted should be as broad and flexible as feasible in order to cover the real needs of the greatest possible number of users.

The voltage ratings for power transformers proposed by the Joint EEI–NEMA Committee were the result of extensive studies of the ratings and operating voltages existing in the industry. The surveys indicated that a total range of taps of approximately 15 per cent is needed. This entire range is not required by enough users to warrant including it in a single standard. Two alternative designs seemed to be the most economical answer, with high-voltage ratings and taps the same for both, and low-voltage ratings of 2,520 volts for one group and 2,400 volts for the other, or multiples thereof. It is expected that most users will find either one or the other, or both, of the alternatives adaptable to their needs, their choice being based on ratios rather than specific tap rating figures.

Digest of paper 50-134, "Selection and Application of Power Transformers," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

H. P. Seelye is with the Detroit Edison Company, Detroit, Mich.

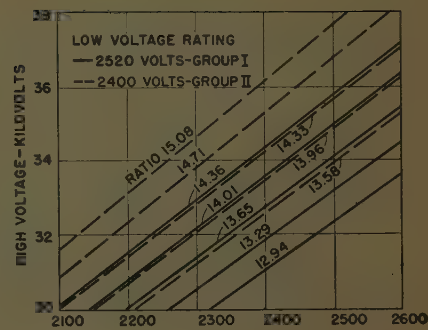


Figure 1. Preferred voltage ratings for 34.5-kv transformers

Figure 1 indicates the various voltages on both high-voltage and low-voltage sides which may be obtained with the two alternative designs within the usual operating range of voltages for 34.5-kv and 2,400-volt systems.

It is desirable for simplicity and economy to standardize on as few kilovolt-ampere ratings as feasible. Standard ratings offered by the manufacturers have been in steps which were unnecessarily small for an individual user. It seems probable that the number of ratings can be reduced. In the range from 750 kva to 15,000 kva there are 13 ratings with 28.5-per cent steps. It is believed these can be reduced to eight or nine ratings with steps of 45 to 55 per cent.

Modern practice calls for the exclusion of air from free access to the oil in a power transformer because of its deteriorating action on the oil. The simplest method is the "sealed tank" design in which the tank is completely sealed, with a cushioning space of proper proportions above the oil or in an auxiliary gas expansion tank. The simplicity of this type commends it for all sizes for which it can be justified by design, tests, and experience.

The changes introduced in materials and designs for transformers in recent years, while producing marked improvement in other directions, have seemed to tend toward more noise. From the user's standpoint, noise from transformers frequently means greater cost for installation. It is very desirable that all practical means for reducing transformer noise levels be developed as a means of minimizing the trouble and expense which the users must incur in transformer applications.

The load-temperature characteristics of a transformer have a direct bearing on the economy of its application and operation. For the most effective use of capacity, the loading should be related to operating temperatures, which are a function of ambient temperatures and the characteristics of the load curve.

The individual user's chief objective in selecting his transformer is, naturally, to promote good service and economy on his own system. Most users will derive appreciable eventual benefit from the existence of sound and comprehensive standards.

Transmission Substation Design

A Departure From the Usual

E. V. SAYLES
FELLOW AIEE

New design features for substations have proved their value. The overhead conduit system which permits the complete elimination of all underground ducts results in greatly reduced costs and time for construction. The purchase of more than 2,000 tons of steel of the Erecticon design has fully demonstrated its savings in cost, and it is now used for not only all new substations in the system but for many other structural applications as well. Alterations to existing structures can usually be made with the use of these standard parts, and certain Erecticon parts can be used in the overhead and underground distribution systems.

A DEPARTURE from the usual design of any part of the electric plant is justified only if substantial gains can be realized in operation, maintenance, safety, or over-all costs. With operation, maintenance, and safety reasonably well accounted for in many excellent designs, the development of new designs admittedly must be directed toward the goal of lower investment and its components of standardized methods, simplified construction, and courage to depart from tradition when judgment dictates.

The transmission substations of the Consumers Power Company system perform the normal functions of transforming from the bulk power transmission voltage to a lower subtransmission voltage, in this case from 138,000 volts to 46,000 or 23,000 volts. The service area consists of some 25,000 square miles and contains about 1,500 miles of 138-kv lines together with some 2,500 miles of 46-kv and 23-kv lines. The 138-kv system serves some 25 major load centers having individual demands of from 15,000 to 100,000 kw. Long-range power supply studies showed that, for every 100,000-kw increase in peak demand, it would be necessary to add about 135,000 to 140,000 kva in transmission substation capacity and, with the system peak estimated to increase some 300,000 kw in the five postwar years, it was apparent that a substantial increase in the number and capacity of transmission substations would be necessary. (Actually, the system peak was 873,000 kw in 1949 compared with 533,000 in 1945, an increase of 340,000 kw.) To meet this demand, nine new transmission substations and additions totaling 345,000 kva have been completed since 1945 and six new substations and additions totaling 245,000 kva are now under construction or are planned for completion by the end of 1952. Faced with such an extensive program in 1945 with constantly rising costs, a re-examination of existing substation designs was justified even though current designs were satisfactory when they were viewed from an operation, maintenance, and safety standpoint.

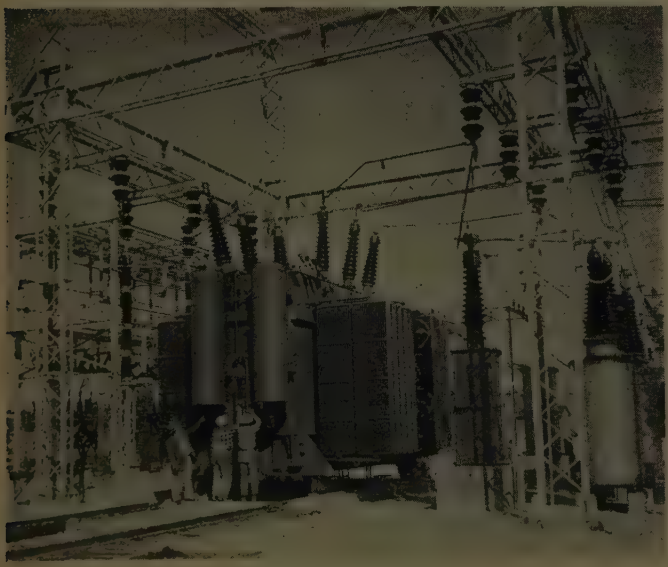


Figure 1. This transmission substation shows the adaptability of the Erecticon design for the installation of a 100,000-kva 138,000/120,000-volt regulating autotransformer on one of two similar interconnections with the Detroit Edison Company

ACCOMPLISHMENTS OF NEW DESIGNS

ENGINEERING STUDIES for the purpose of developing new designs were directed along the lines of accomplishing, in so far as possible, the following items:

1. Greater standardization of equipment ratings, which would permit
2. Standardized electrical and structural designs and construction methods, with
3. Use of standard drawings and bills of material, permitting
4. Quantity purchase of materials and equipment for all substations, and
5. Reduction in time required for design and construction; all for the purpose of securing
6. Lower investment cost.

Full text of a conference paper presented at the AIEE Great Lakes District Meeting, Jackson, Mich., May 11–12, 1950.

E. V. Sayles is General Engineering Supervisor with the Consumers Power Company, Jackson, Mich.

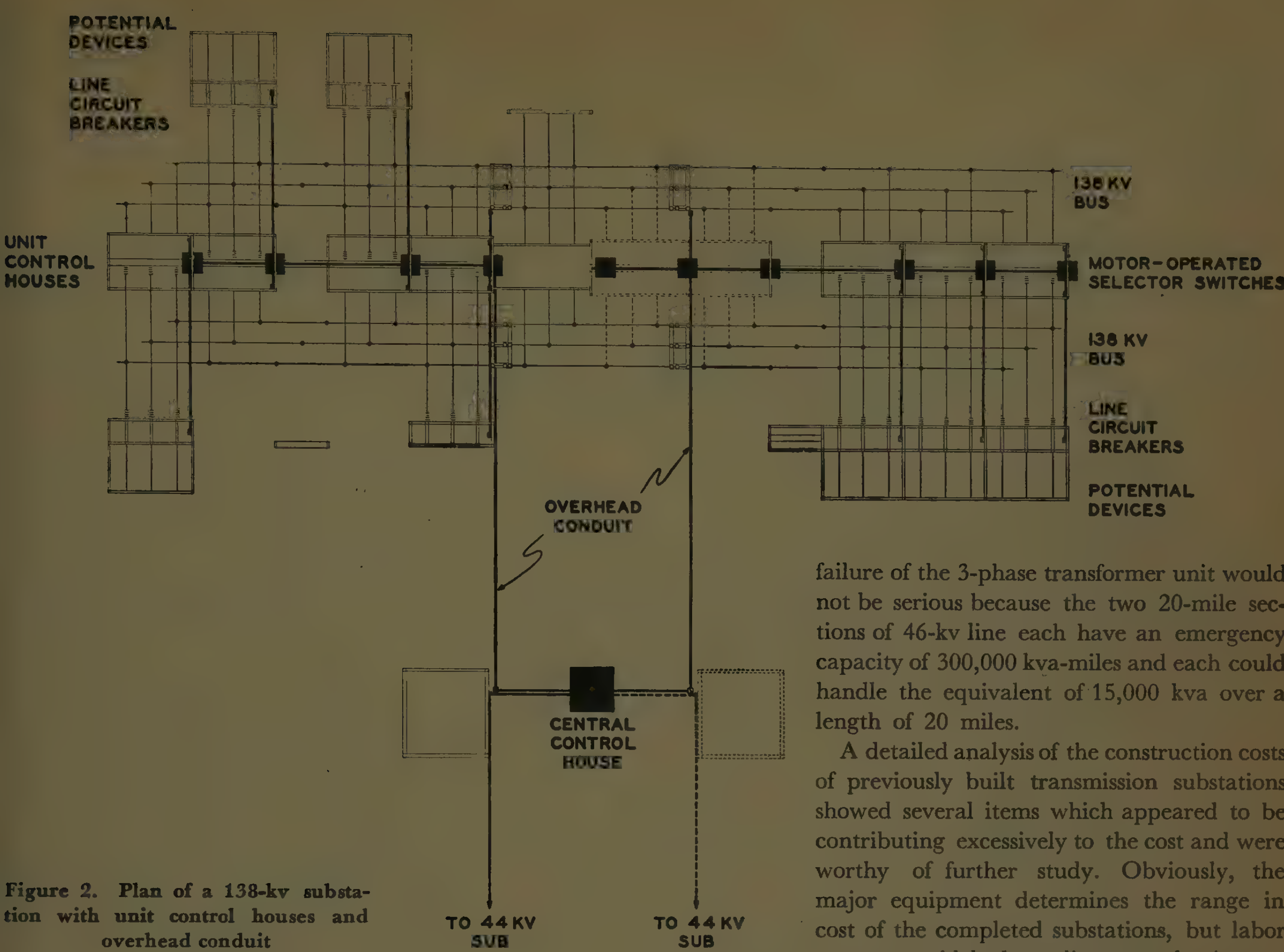


Figure 2. Plan of a 138-kv substation with unit control houses and overhead conduit

failure of the 3-phase transformer unit would not be serious because the two 20-mile sections of 46-kv line each have an emergency capacity of 300,000 kva-miles and each could handle the equivalent of 15,000 kva over a length of 20 miles.

A detailed analysis of the construction costs of previously built transmission substations showed several items which appeared to be contributing excessively to the cost and were worthy of further study. Obviously, the major equipment determines the range in cost of the completed substations, but labor costs vary widely depending upon the time required for completion of the various items of construction. With the costs of equipment and material reasonably fixed, designs which require less material, less labor, or labor which is easier to perform offer the only possibilities of costs reductions.

One of the possibilities of cost reduction was the steel structure. This had always consisted of rolled or latticed columns, trusses, and miscellaneous structural parts. Although similarity of design between substations already existed, detailed designs and erection drawings were required for the structural portion of each substation.

PATTERN FOR POWER SUPPLY

Before any standardization of transformer banks can be made, system studies must develop a pattern for major power supply points and probable load increments to be supplied at these points. In the Consumers Power Company system, major load centers—industrial centers or locations at which subtransmission lines converge—occur quite regularly at either 20- or 40-mile intervals and the loads at these centers are well represented by units of about 25,000 or 30,000 kva. For this reason, a 30,000-kva 3-phase transformer was chosen as a standard-size step-down unit to supply the subtransmission system at these locations.

The principal subtransmission voltage of the system is 46,000 volts. On the basis of 10-per cent voltage drop and 90-per cent power factor, a 46,000-volt line has a rating of approximately 200,000 kva-miles. With major power centers 40 miles apart, one 46-kv line could deliver the equivalent of 10,000 kva at half this distance—20 miles—with satisfactory voltage conditions, or it could deliver 15,000 kva, if the power factor of the load was higher and the voltage drop somewhat greater. However, when the load approaches 15,000 kva at a point midway between two transmission substations 40 miles apart, a new transmission substation is located approximately midway between these points. While this load may start at 15,000 kva, it is permitted to increase to twice this value until the rating of a 30,000-kva transformer is exceeded. During this time, a

NEW STRUCTURAL DESIGNS

Prior to these studies, Consumers Power engineers, in connection with the design of new distribution substations, had developed a standardized set of structural parts (known as the Erecticon design) with which any type of outdoor substation structure could be assembled. This design has been fully described in several previous technical articles,[1,2] but it consists essentially of two standard trusses used interchangeably as columns, one truss with a cross section 12 inches by 12 inches and the other 12 inches by 30 inches. These are rigid trusses fabricated principally from 3-inch angles and are shop welded and assembled using jigs to insure close uniformity of dimensions and the matching of holes which are punched at 3-inch intervals in the corner faces of all trusses. All trusses are galvanized after fabrication. They are standard, in lengths of from four feet to 20 feet, in multiples of two feet and can be

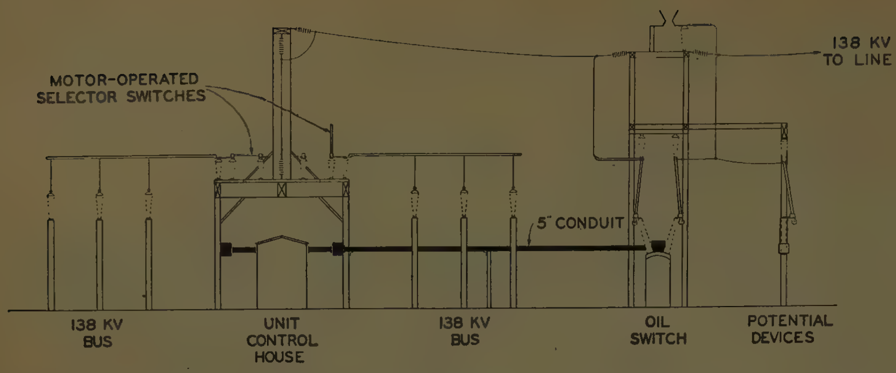


Figure 3. Cross section of 138-kv substation with unit control houses and overhead conduit

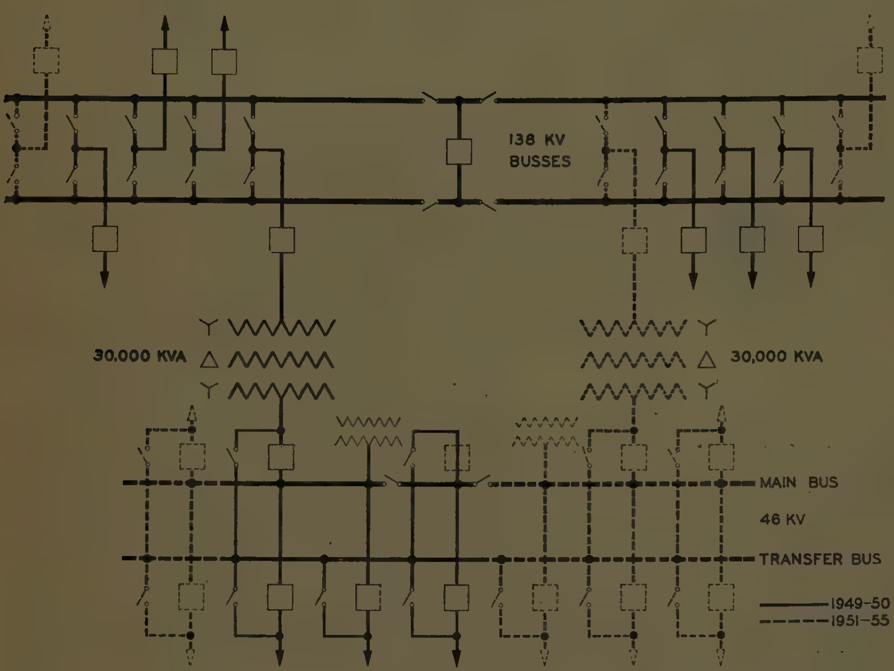


Figure 4. One-line wiring diagram of the Verona Substation, Battle Creek, Mich., showing the type of connections generally used for the major transmission substations on the system

bolted end to end with internal bolts to make a continuous truss or column of any desired length. In addition, other standard steel parts are available consisting of channels, angles, brackets, and plates, which are used for assembling trusses into a complete structure and for installing equipment and various attachments to the structure. About 100 individual stock parts permit the erection of any substation structure regardless of its size or voltage (Figure 1).

The use of these structural members has resulted in the adoption of standard dimensions for line and transformer bays, all of which makes possible the use of standard electrical layouts which are used as erection drawings and which include a bill of material showing every item required. Standard drawings are available for all 138-kv line or transformer bays and any other bays of greater or lesser dimensions that are commonly used. One advantage of this design is its use of standard parts rather than the use of standard dimensions of completed structures. For example, the width, length, or height of a substation bay can vary over a wide range without affecting the steel design. Likewise, column footings are all the same and require the same steel connections and anchor bolts, so that foundations can be completely standardized and a permanent type of metal form can be used.

Experience obtained in the building of about a dozen major transmission substations (and about 150 unit-type distribution substations which use the same steel parts) shows that substantial reductions in cost have been effected. A large transmission substation will use about three-quarters of the weight of steel required if it had employed standard rolled or bolted sections and erection costs are about one-half. Considering all costs of material and labor, the resulting savings are about one-third of generally accepted designs.

OVERHEAD CONDUIT SYSTEM

THE CENTRAL CONTROL BUILDING of a large transmission substation with its control cable and underground conduit system has always seemed to contribute in too large a measure to the cost of the substation. The size of this building itself, when provision is made for future switchboard and control panels, results in an expensive structure while the labor of installing the underground ducts and control cable is one of the very large items of cost. It was apparent that, if underground ducts and long lengths of control cable could be eliminated, another reduction in costs could be realized.

With line and transformer structures standardized, it seemed logical to extend this standardization to include the switchboard and control equipment required for the operation of this unit itself. Obviously, the least amount of cable and conduit is used when the controls are located adjacent to the equipment to be controlled. This is exactly what was done. A small steel control house is installed in each line or transformer bay and provides the location for the switchboard and relay equipment. All control cables are installed in overhead steel conduit (Figures 2 and 3).

While the Erecticon structural design has been used for all major transmission substations in the Consumers Power Company system since 1945, the completion of the Verona Substation at Battle Creek marks the first large substation where the Erecticon design has been combined with the overhead conduit system. This substation presently includes connections for six 138-kv overhead lines. It includes a double bus with bus-tie circuit breaker and one circuit breaker per circuit connection with motor-operated selector switches for transfer between busses (Figure 4).

The 138-kv portion of the substation was first energized in August 1949, and construction is now in progress which provides for a 30,000-kva 138-46-kv transformer and a new 46-kv switching station which will use one circuit breaker per connection with a main and transfer bus. Within the next 5-year period, the substation should include eight 138-kv lines, two 30,000-kva transformers, and eight 46-kv lines.

PROTECTIVE RELAYING

THE VERONA SUBSTATION is essentially a fully automatic one and, although an operator is regularly in attendance, it is because of the great importance of Verona as a central location in the company's transmission system rather than the need for performing routine operations. Each 138-kv line circuit breaker is equipped with a single-shot recloser, a synchronism check relay, and two undervoltage relays so connected that the circuit breakers will reclose automatically when the line is de-energized, or the line and bus are both energized and in synchronism.

For phase protection on each line circuit breaker, step distance directional relays are used and, for ground protection, directional overcurrent relays are used. Where equal ground currents in either direction are possible, directional instantaneous ground relaying is provided.

The bus-tie circuit breaker in all of the large transmission substations serves a dual purpose in that it not only performs the normal functions of any bus-tie circuit breaker but it also may be regularly used to take the place of any line circuit breaker. One reason for this is the fact that all line circuit breakers are equipped with by-pass disconnects of a type which permits the circuit breaker to be readily removed from service without circuit interruption, but in this case the line is connected directly to one bus with all remaining circuits connected to the other bus.

For normal operation, phase protection on the bus-tie circuit breaker consists of nondirectional phase and ground relays. The phase relays have one step impedance element to trip with definite time delay (to pick up the first step of the line relays) and a voltage-controlled overcurrent element as the second step. For operation as a line circuit breaker, step distance directional phase relays and directional overcurrent ground relays are used similar to the relaying provided on all line circuit breakers. Two selector switches are provided, one for selecting the proper phase relays and the other for selecting the proper ground relays. These selector switches also change taps on auxiliary current transformers supplying the line relays of the bus-tie circuit breaker so that these relays may be altered to protect 138-kv lines without changing bus-tie relay settings.

UNIT CONTROL HOUSES

ALL PROTECTIVE and control relays and metering equipment are mounted on switchboard panels of the company's standard design. These panels are installed in the control house or cubicle located near the center of each 138-kv substation bay. They are 96 inches in height with the relay panel being 32 inches in width and the control panel 20 inches. Each building is 8 feet by 8 feet by 10 feet high, of steel construction, and insulated with fiber glass.

Each control house is self-contained in so far as its heating, lighting, and power supply are concerned. Station power at 480 volts three-phase is supplied from substation transformers, and 120/240 volts single-phase is obtained by use of a small dry-type transformer in each control house. Direct current at both 120 volts and 48 volts is supplied from the central control house. These several voltages are distributed from a common control panel equipped with suitable protective devices. A telephone jack is included in the panel and a thermostat for control of a small heater.

All conduits in the substation are overhead (Figure 5). To connect the ten control houses in the Verona Substation, a 5-inch steel conduit extends the full length of the station, a distance of about 300 feet, at an elevation of 10 feet above the yard level. This conduit contains station power supply, d-c supply, and remote control cables. There is also a 5-inch conduit in each bay which extends from the control house to a central location from which individual conduits are extended to the various operating devices.

The ceiling of each control house serves as the location for ample size cross ducts with removable covers. These ducts enclose the a-c and d-c busses which extend the full length of the station and to which connections are made in each unit house. All other control cables which enter the house utilize these overhead ducts from which they connect directly to the top of the switchboard panels.

CENTRAL CONTROL HOUSE

THE CENTRAL CONTROL HOUSE is approximately 16 feet by 17 feet and is 10 feet high and of the same general type as the small unit houses. In addition to the 120-volt and 48-volt batteries and charging equipment, it contains a miniature remote control and metering panel for the 138-kv equipment. From this console, any circuit breaker can be controlled, any line transferred to either bus, the operation of any circuit breaker determined, and complete readings noted from miniature indicating instruments.

The 46-kv portion of the transmission substation follows much the same pattern as the 138-kv sections using the same

Figure 5. Typical 138-kv line bay with unit control house and 5-inch overhead conduit at the Verona Substation, Battle Creek

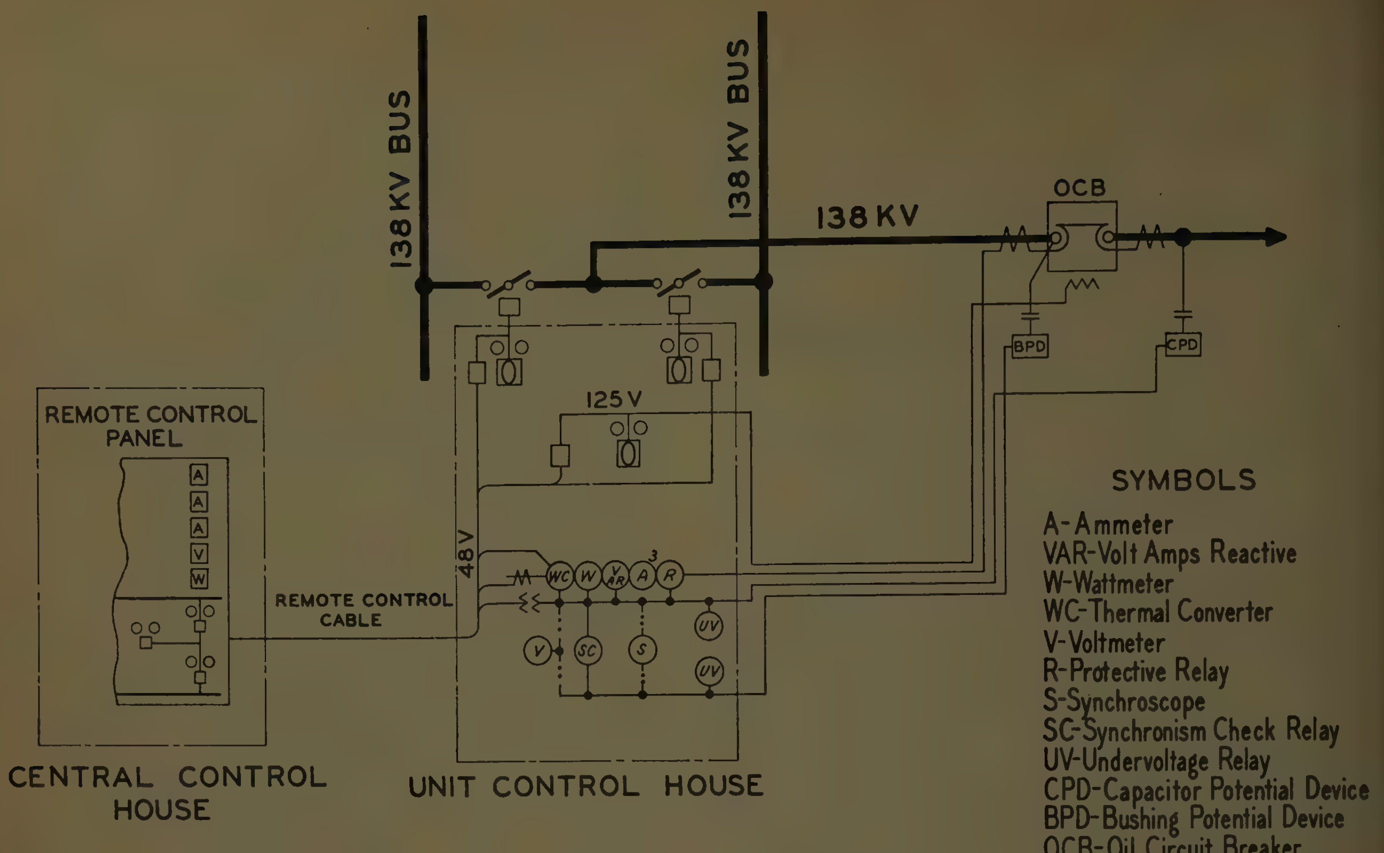


Figure 6. Schematic diagram of remote control wiring at Verona Substation at Battle Creek showing the relative locations of relays, meters, and protective equipment

type of structural steel, foundations, overhead conduits, and individual control houses in each 46-kv bay. The individual control houses are identical with those used for 138 kv. However, for 46-kv control equipment, one control house is large enough to accommodate two lines. Years of experience with 46-kv circuits show that it is unnecessary to extend their control facilities to the central control house, in fact, that automatic reclosing of the circuit is preferred. Three-shot reclosing relays are provided and an indicating lamp is located on the outside of each house to indicate the lockout of any circuit. However, control and indication of total load on the 46-kv winding of the 30,000-kva transformer bank is provided on the console panel in the central control house.

REMOTE CONTROL AND METERING

THE REMOTE CONTROL PANEL is mounted in a vertical position above the operator's desk in the central control house. For each 138-kv circuit, there are three ammeters, a voltmeter, and a wattmeter. The miniature instruments are arranged vertically on the panel with telephone-type operating switches below. A mimic bus with indicating lights is also included. Remote control and metering circuits were designed to be adaptable to supervisory control.

To reduce the exposure on the current and potential transformer circuits for the protective relays, these circuits are not carried directly to the central house but are reduced in voltage or current magnitude to supply the miniature instruments. This is accomplished in the following manner (Figure 6):

1. Voltage indication is obtained by using high reactance transformers and series resistors in each unit control house to supply about ten volts to the rectifier-type voltmeters in the central control house.

2. Ammeter indication is obtained by using auxiliary current transformers with shunting resistors in each phase of the main current transformer secondaries at each unit control house.

3. Kilowatt indication is obtained by the use of thermoverters at each unit control house and microammeters calibrated in megawatts at the central control house.

It is apparent that these remote metering circuits are readily adapted to the use of telephone-type cable. One 19-conductor Number 19 wire cable is installed in the overhead conduit system between each unit control house and the central control house. This small control cable furnishes the remote metering circuits, the control circuits for all station circuit breakers and selector switches, the controls for yard lighting, and a telephone circuit to all unit control houses. At the same time, there is little concern regarding short or open circuits in the cable having any effect on the relaying or indicating instruments in the unit houses.

REFERENCES

1. Substation Design Remains Flexible with Erecticon Assembled Sections, **E. V. Sayles.** *Electrical World* (New York, N. Y.), volume 128, number 19, November 8, 1947.

2. Planned Substations Can Cost Less, **E. V. Sayles.** *Electrical World* (New York, N. Y.), volume 128, number 21, November 22, 1947.

3. Automatic Relayman Changes Breaker Settings, **H. P. Dupuis, B. P. Carr.** *Electrical World* (New York, N. Y.), volume 133, number 9, February 27, 1950.

Locomotive Wheel-Slip and Wheel-Lock Protection

R. M. SMITH
ASSOCIATE AIEE

ACCIDENTS HAVE OCCURRED within recent years caused by the locking of driving wheels on diesel-electric locomotives. High-speed wheel slip is one cause of locked axles. Hence it is desirable to have some means of protecting a locomotive against wheel slip, wheel lock, motor overspeed, and wheel slide during braking.

Wheel slip may be divided generally into two classes: those cases which occur at 20 miles per hour or less, and those which occur at higher speeds. At low speeds, it is possible for the motor torque to give tractive-effort levels greater than the weight on the locomotive axle multiplied by the normal factor of adhesion. At some speed around 20 miles per hour (depending upon the torque characteristics of the motor under consideration) the motor torque falls to a level such that the factor of adhesion must be greatly reduced in order to precipitate wheel slip.

Under very favorable conditions, factors of adhesion of 40 per cent at speed have been observed. Under very adverse conditions, factors as low as four or five per cent occur at standstill. These, however, represent extreme cases and occur because of some unique rail conditions. Only general causes of wheel slip will be discussed.

A tentative set of specifications, based on a study of actual wheel slips observed in service, is suggested. The requirements laid down will obviate shortcomings found in currently used protection systems. There are, at present, a number of methods of detecting locomotive wheel slip.

1. *Detection of unbalance between traction motors.* This system is the one in most common use today. In order to care for normal transient voltages and to allow for operation in all series-parallel traction motor connections, it is necessary to make the relays measuring this unbalance comparatively insensitive. In addition, protection is only furnished when power is on the motors.

2. *Residual motor voltage measurement.* This system is an auxiliary to the protective relay mentioned in the first method. With power off, a relay is used to measure residual motor voltage. Variations in residual motor voltage might cause occasional malfunctioning.

3. *Addition of pole face windings.* A frequency output from pole face windings in all the traction motors is compared to detect any speed differences between motors. Expensive alterations to the traction motors are required to use this detection method.

4. *Axle-mounted velocity detectors.* A device used on passenger cars to prevent overbraking can be adapted to measure differences in locomotive axle speed. A commutator and brush set are mounted on each axle and difference in velocity between any two axles is measured.

5. *Locked axle protection.* A recently announced unit for mounting on the journal box consists of a centrifugal switch which trips out at a predetermined speed to notify the engineer of a locked axle.

6. *Individual axle generators.* An elaborate system was installed on a gas turbine electric locomotive. Individual axle generators were used to measure differences in speed between any axle and the average for all.

At low speeds, the protective devices should operate at speed differentials of about five miles per hour. At speeds of 40 miles per hour or greater, the allowable slip should be increased to permit a slip equal to 10–15 per cent of locomotive speed. The reason for this tapering of sensitivity at higher speeds is to allow self-recovery due to changes in rail condition. Starting of high-speed slip is usually a transient phenomenon. Therefore, if normal rail conditions are restored, wheel slip will often stop without requiring corrective action, with its attendant loss in tractive effort.

During dynamic braking, it is desirable to be able to load each wheel up to the maximum available factor of adhesion. If the traction motors are properly connected, it is not possible to lock wheels during dynamic braking, because at zero speed the power output of the motor is zero. The fact that there is little likelihood of damaging the traction motor or the wheels during small values of slide in dynamic braking, coupled with the desire to get maximum braking effort from the locomotive, should allow higher values of permissible slide to be established. A value may be tentatively set at 20 per cent of the locomotive speed or ten miles per hour, whichever is higher.

The correction initiated by such a wheel-slip scheme should be automatic and should be limited to the unit affected. In any practical control scheme requiring action by the engineer, he can only correct slipping on any one unit by reducing the power on all. The resultant loss in tractive effort is undesirable. In overspeed, the time lag occurring between the signal to the engineer and the actual reduction in power could be great enough to allow permanent damage to the motor, hence the requirement for automatic correction. A cab indication of slip is necessary to warn the engineer of repeated slips so that he can reduce power. Locked-axle protection definitely requires a cab indication.

Two approaches to this problem exist. One is to add more devices to the schemes already used to provide partial protection. The other is to develop one integrated system for the whole protective function. Modifications to existing system have been made by several railroads, and these are now undergoing tests.

Digest of paper **50-181**, "Locomotive Wheel-Slip and Wheel-Lock Protection," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

R. M. Smith is with the General Electric Company, Erie, Pa.

Simple New Resistance-Type A-C Load-Flow Board

WALDO E. ENNS
MEMBER AIEE

NETWORKS of circuits are replacing the radial type in many places for transmitting and distributing electric power. One of the disadvantages of networking is the complexity of the problems to be solved to determine what changes or additions to a network should be made to obtain the desired operating characteristics at a minimum cost. The conventional type of a-c board has provided engineers with an accurate and speedy tool for the study of complex network problems. Now another type of a-c board using only resistance circuits and no generator or load units has been built by the Portland General Electric Company. It is operating successfully in solving complex network problems accurately and speedily.

The over-all dimensions of the cabinet section of the board is 66 by 82 by 18 inches, and a small desk is attached. Present requirements, for the company's studies, are about 40 busses and 60 circuits, whereas 60 busses and 92 circuits are available. All control keys and push buttons are located in the desk top making the selection of any bus or circuit easy. A bus-voltage plugging section supplied from a single multitapped autotransformer and used to balance the network loading is located below the instruments. Indicating instruments read base voltage, per cent megawatts or reactive megavolt-amperes, and per cent bus voltage. Plugging panels are supplied for setting up the complete network and for setting up the circuit constants Z^2/R and Z^2/X.

Figure 1 shows the single-line diagram and recorded results of a study typical of those being made. As with any load-flow study, most of the time is used in deciding what to study and in preparing network data for the study. After a plugging diagram and circuit constant tabulation is prepared, it takes three to four hours to set up and check back on the plugging. The time required to adjust bus voltages to obtain simulated generation and loads at the busses is usually between two and four hours.

Although the Portland General Electric Company a-c board is designed to make only load-flow studies, a modified design has been devised which will make short-circuit studies as well without increasing the size or cost.

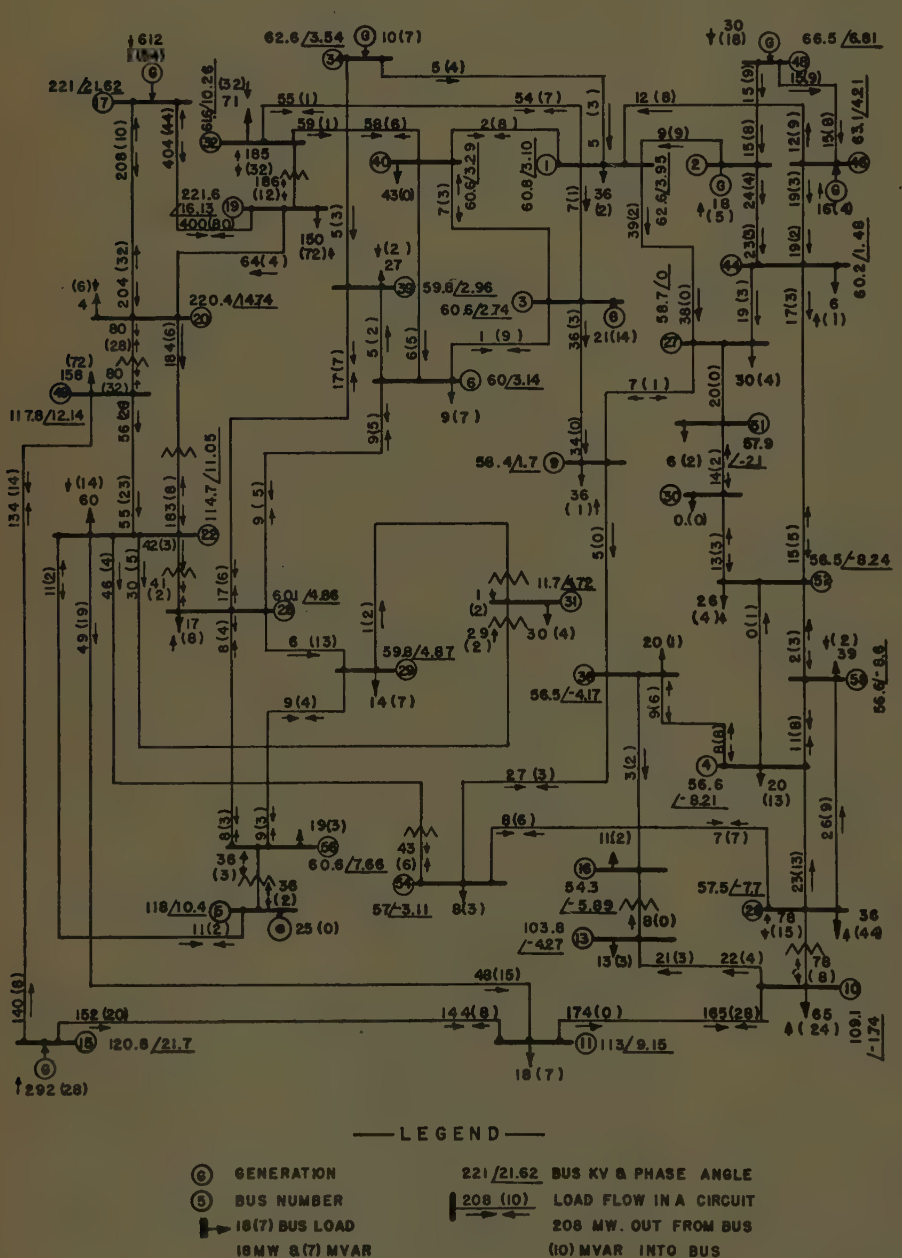


Figure 1. Typical load-flow problem solved on the resistance board

REFERENCES

1. A Simple Calculator of Load Flow in A-C Networks, **Waldo E. Enns.** AIEE *Transactions*, volume 62, 1943, pages 786–90.

2. Network Analyzer, **Waldo E. Enns.** United States Patent 2,491,095.

3. Apparatus for A-C Network Analysis, **Waldo E. Enns.** United States Patent 2,323,588.

Digest of paper 50-172, "A Simple New Resistance-Type A-C Load-Flow Board," recommended by the AIEE Committees on Computing Devices and System Engineering and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Not scheduled for publication in AIEE *Transactions*.

Waldo E. Enns is with the Portland General Electric Company, Portland, Oreg.

A Distributed Power Amplifier

A. P. COPSON

FOR YEARS, a goal of the designer has been to increase the frequency response of vacuum-tube amplifiers. Considerable success has been achieved, with the design of the video amplifiers, in obtaining a frequency response from 30 or 40 cycles up to 4 or 5 megacycles. This is adequate for present-day television video requirements, but amplifiers with greater bandwidth are needed for many applications, such as video amplifiers for improved television, wide-band telephone repeaters, and oscilloscope amplifiers.

The distributed amplifier is a new type of wide-band amplifier, entirely different from the conventional video amplifiers in use today. The innovation introduced is to distribute pentodes across two properly terminated artificial transmission lines, thus substituting the lines for the grid and plate impedances of the amplifier tubes.

The distributed power amplifier will fill this need for an improved wide-band amplifier. Distributed power amplifiers will find use where some power is required over a wide band of frequencies, such as is needed to modulate a television transmitter.

The first part of this article will deal with the basic theory of the artificial transmission line as used in the distributed amplifier. These artificial transmission lines are the chief components of the distributed amplifier.

THE ARTIFICIAL TRANSMISSION LINE

ARTIFICIAL TRANSMISSION LINES are essentially low-pass filters. The filtering action of the line is not the desired quality, but because the inductance and capacitance of the lines are lumped, high attentuation occurs above the cut-off frequency.

These lines are used in distributed amplifiers to utilize the constant input impedance, with frequency, that terminated lines possess. Two lines are used in each amplifier: one constitutes the plate impedance, the other the grid impedance. By so doing, the distributed amplifier circumvents the main limiting factor of the high-frequency response of video amplifiers, which is the lowering of the output load impedance by shunt capacitive reactance.

A single-section low-pass filter terminated at both ends by m-derived half-sections and terminating resistors is shown in Figure 1. These m-derived half-sections are basic prototype filter half-sections with their series and shunt impedances operated on by a constant m. Setting the series inductance of the prototype filter section as L and the shunt capacity as C, the values for the m-derived half-sections are

$$\text{Series inductance} = m(1/2)L \tag{1}$$

$$\text{Shunt inductance} = 2\left(\frac{1-m^2}{4m}\right)L \tag{2}$$

$$\text{Shunt capacitance} = (1/2)mC \tag{3}$$

Figure 2 shows the input impedance of the terminated filter of Figure 1 for different values of m. The most desirable input impedance is obtained when m is about 0.6. For this condition the input impedance will stay approximately constant over frequencies from zero to about 0.8 cut-off frequency. This input impedance will appear essentially resistive over the useful portion of the passband. If the cut-off frequency is made sufficiently high, a line terminated with m-derived half-sections and terminating resistors will work well as the load impedance of a video amplifier.

THE DISTRIBUTED AMPLIFIER

THE BASIC wiring diagram for the distributed power amplifier is shown in Figure 3. The tubes are placed on the grid and plate lines at intervals where the shunt capacitance of the prototype filters occur. This puts the individual tube gains in parallel, as each of the tube currents flows through the output terminating resistor.

One of the chief advantages of the distributed amplifier is that the individual tube gains add. In conventional video amplifiers, tube gains multiply. The distributed amplifier may, therefore, employ plate-line impedances of such a low value that the individual tubes have gains less than unity. Because of the gain addition, the over-all gain will be considerably greater than unity. A low value of plate-line characteristic impedance, usually designated Z_0, is necessary to obtain a wide band of frequency re-

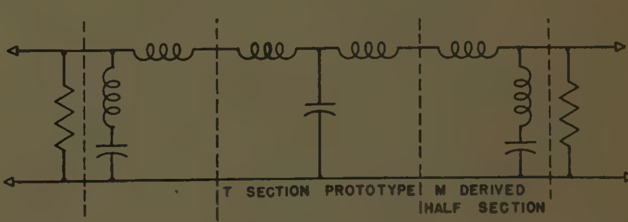


Figure 1. Single-section low-pass filter with m-derived half-sections and resistors terminating both ends

The original work of Dr. E. L. Ginzton and others is acknowledged for first presenting the idea of the basic distributed amplifier. Much work has been done at Stanford University and elsewhere toward developing this basic and other more intricate distributed amplifiers. The help and valuable ideas of Robert Michaels and J. J. Wittkopf are gratefully acknowledged along with the helpful guidance of Professors A. L. Albert and F. O. McMillan. The help of Robert Stalley in obtaining some of the mathematical derivations is acknowledged.

A. P. Copson is with the Bonneville Power Administration, Portland, Oreg.

This paper was written when Mr. Copson was a senior at Oregon State College and was awarded first prize in the Student Paper Contest.

sponse. Z_0 will be shown to be an inverse function of the cut-off frequency, given a certain minimum shunt capacitance of the tube. Although the individual distributed-amplifier stages inherently have low gain, these stages may be cascaded to get an over-all gain of any value which may be desired.

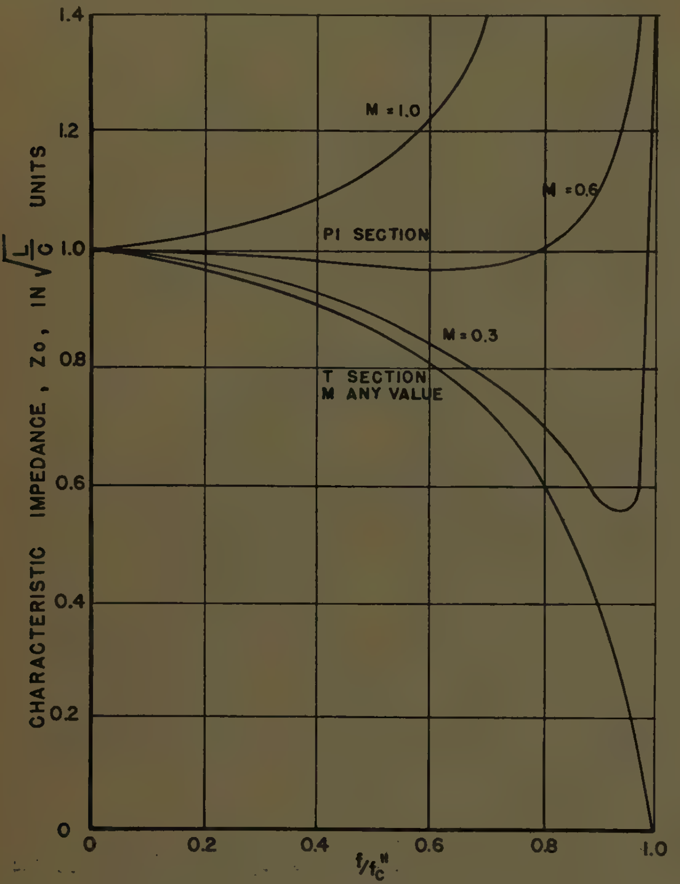


Figure 2. Input impedance characteristics for m-derived terminators

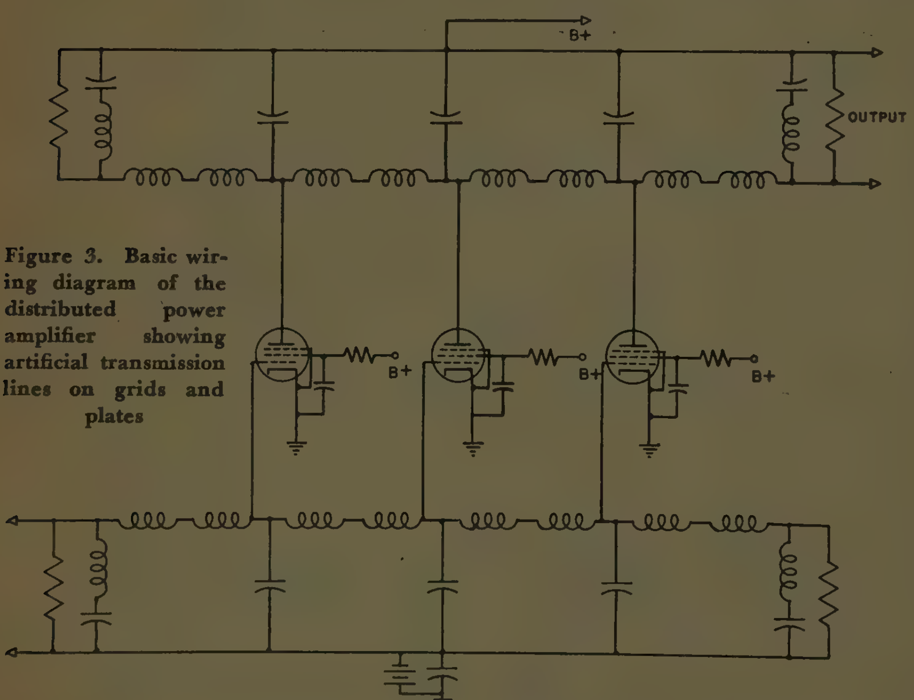


Figure 3. Basic wiring diagram of the distributed power amplifier showing artificial transmission lines on grids and plates

Pentodes are utilized for their high amplification and high plate resistance. Because of their high plate resistance, the disturbing effect the tubes have on the line is negligible. The effective load impedance of each tube is $(1/2)Z_0$. This is true because each tube must deliver current into the line so that the current flows two ways; thus each tube works into two lines in parallel or into $(1/2)Z_0$.

Theory of Operation. The operation of the distributed amplifier may be analyzed on a sine-wave basis. Assume that a sinusoidal voltage is applied to the input terminals at a time t_0. This wave will be propagated down the grid line at the velocity of propagation of the line. The signal will arrive at the grid of the first tube at time t_1. This signal will travel through Tube 1 in transit time d. This transit time will be the same for all the tubes. Current will flow from the plate of Tube 1 into the junction with the plate line. Here the current will divide equally, half going to the left and half to the right. Labeling the current that flows to the right as I_1, this will travel down the plate line with a delay of time t_2. During this time the original grid signal has traveled down the grid line and has arrived at the grid of Tube 2 at time t_2+t_1. This signal will be amplified and applied to the plate line with a delay of time d in Tube 2.

The operating principle of this amplifier depends upon the current I_1 arriving at the junction of Tube 2 and the plate line at exactly the time the signal through Tube 2 arrives there. This will occur if the following equation holds:

$$t_1+d+t_2'=t_1+t_2+d \tag{4}$$

The current from Tube 2 will also split, half to the left, half to the right. The portion that travels to the right, at I_2, will be in exact time phase with I_1. These will add to the resultant wave traveling to the right. This analysis may be continued for as many tubes as are in the amplifier stage.

The discussion thus far has been for sine-wave amplification. It will be necessary to prove that the distributed amplifier will amplify any complex signal that may be applied to the input. In order for the output to be an accurate replica of the input signal, the harmonic components must be in the same relative phase position as they were at the input. For this to occur, the velocity of propagation must be equal for all frequencies. This may be represented

$$V_f=K \tag{5}$$

The velocity of propagation is given, however, as

$$V_f=\omega/\beta=2\pi f/\beta \tag{6}$$

So, for the assumption that the velocity of propagation for each fre-

quency is equal and constant, it may be seen that:

$$2\pi f/\beta = K \text{ or } \beta = K'f \tag{7}$$

However, the phase shift of low-pass filters is not a linear function of frequency but is given

$$\beta = \cos^{-1}(1-\omega^2 LC/2) \tag{8}$$

This function is plotted in Figure 4. It is seen to be approximately a linear function of frequency over the lower portion of the passband. The relationship is not linear for the higher portion of the passband, breaking away and rising at an increased slope. This discrepancy occurs approximately at the same frequency that the Z_0 of the lines deviates from normal. Thus, the amplifier will have its passband limited by both phase and frequency distortion.

An interesting study may be made to determine how the inductance of the prototype filter must be varied with frequency to keep the phase shift a linear function of frequency. The mathematical derivation of this is given in Appendix I.

In reality, the phase shift is not as nonlinear as is predicted by theory. This is true because the actual filter has resistance and distributed coil capacitance which combine to make the phase shift more nearly a linear function of frequency.

As is well known, the phase distortion of audio amplifiers is zero for the frequency range over which the amplifier has flat frequency response. This indicates that the phase distortion of the distributed amplifier could be made negligible over essentially the entire amplification band.

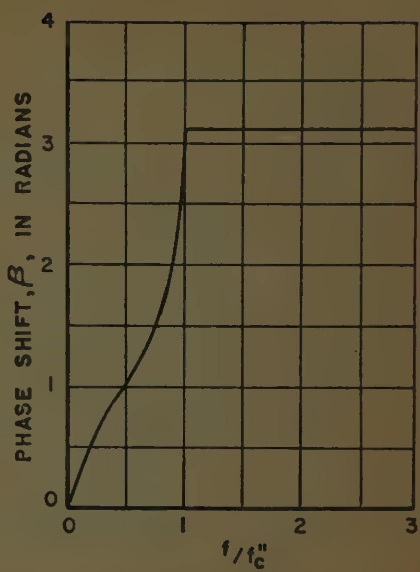


Figure 4. The phase-shift characteristic of a low-pass filter rises rapidly at frequencies where the characteristic impedance Z_0 of the lines deviates from normal

CONSTRUCTION OF AMPLIFIERS

Two amplifiers were constructed during this investigation, a distributed power amplifier and a distributed voltage amplifier.

The Distributed Power Amplifier. The distributed power amplifier is shown in Figure 5. Its amplifying tubes are type *807*, a small transmitting beam-power tetrode. The schematic diagram is essentially the one given in Figure 3. As the *807* has its plate connection on the top, it was possible to construct the amplifier with the two artificial lines above the chassis and the amplifying tubes placed across the two lines. The subchassis holds the tube bases and serves as an effective shield between the grid and plate lines. This is quite important as it is quite easy for oscillations to occur if there is coupling between the grid and plate lines.

Figure 5. The subchassis of the distributed power amplifier holds the tube bases and shields the grid lines from the plate lines

Originally, the power amplifier was constructed with the grid and plate lines equal in all respects. The characteristic impedance Z_0 of the plate equalled the Z_0 of the grid and was set at 482 ohms.

This amplifier was tested in its operation, then the Z_0 of the grid line lowered to 200 ohms. In order to permit the amplifier to operate, the capacitance of the grid line was increased so that the product of the inductance and capacitance of the grid line was the same as originally. Since the phase shift of the line is proportional to this product, the amplifier should and does operate the same as before.

The design of the distributed power amplifier is a compromise between wide frequency response and high power output. The initial design equation used is the one for the shunt capacity of low-pass filters:

$$C = \frac{1}{\pi Z_0 f_c''} \tag{9}$$

where f_c'' is the upper cutoff frequency of the line. The compromise between wide frequency response and high characteristic impedance Z_0 may be struck if the shunt capacitance of the line is known. A high value of Z_0 is desired to obtain a high power output as the power output is proportional to the Z_0. With f_c'' and Z_0 fixed, the series inductance of the prototype filter may be calculated

$$L = Z_0/\pi f_c'' \tag{10}$$

Next, the values of the inductances and capacitances in

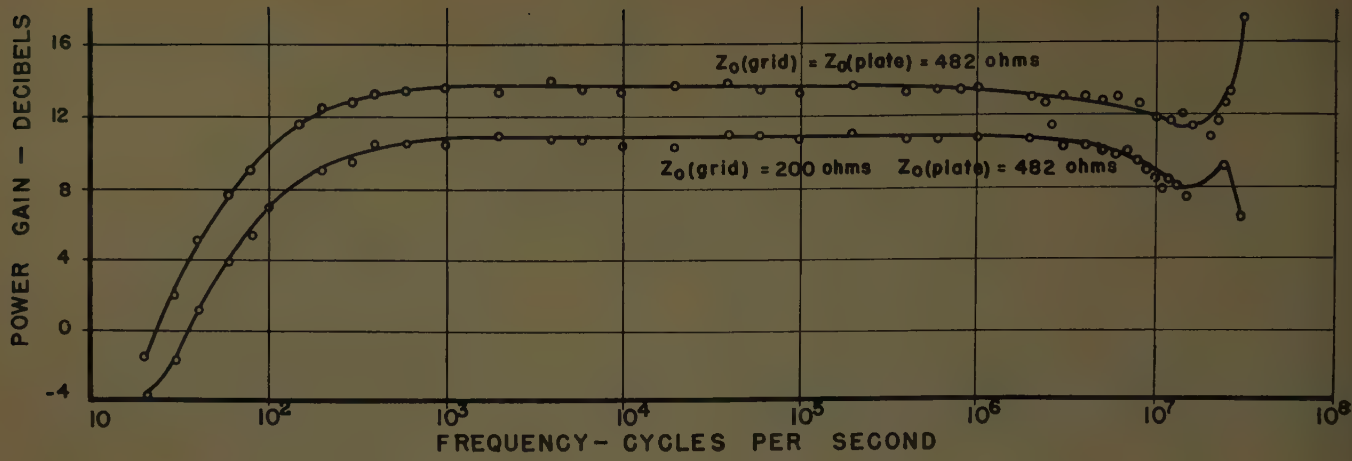


Figure 6. Frequency response characteristics for the distributed power amplifier

the *m*-derived terminating half-sections may be calculated with the formulas given.

Some calculated values for the prototype filter sections are: Z_0 of 482 ohms, cutoff frequency of 55 megacycles, and an inductance of 2.79 microhenrys. The shunt capacitance of both lines is 11 micromicrofarads.

The characteristic curves for the vacuum tubes used are necessary to calculate the voltage or power output for the amplifier. A load line is drawn on these characteristics at a slope equivalent to a load resistance of $(1/2)Z_0$. The swing of grid voltage permitted is controlled by the amount of nonlinear distortion allowed in the amplifier. The output voltage swing corresponding to the grid voltage swing must be multiplied by the number of tubes in the stage to obtain the over-all output voltage of the stage. The power output is then merely E^2/R for the output terminating resistor.

The frequency response of the power amplifier was determined by connecting input terminals of the amplifier to a signal generator and connecting a vacuum-tube voltmeter to the input and output terminals to find the voltage gain. Voltage gain may be converted to decibels of power gain by the formula

$$\text{Decibels power gain} = 20 \log (E_{out}/E_{in}) + 10 \log (Z_{in}/Z_{out}) \qquad (11)$$

The upper curve in Figure 6 shows the frequency response attained for the power amplifier. It is quite flat over a band from 100 cycles to 20 megacycles from where the power gain takes a sharp rise. The fact that this happens far below the value predicted by the characteristics for the Z_0 of the lines indicates that some experimental deviation from the calculated values caused the Z_0 to vary with frequency.

Tests made to determine the phase-shift distortion and the nonlinear distortion of the amplifier showed only qualitatively that both of these distortions are low in value over the passband.

It is desirable to show that it is not necessary for the two lines to be identical for the amplifier to operate satisfactorily. Therefore, the grid line was altered so that it had the following characteristics: Z_0 of 200 ohms, inductance of the prototype of 1.11 microhenrys, and a shunt capacitance of 27.7 micromicrofarads. The new *m*-derived terminating components may be computed from these data.

This modified power amplifier was tested for frequency response. These results are shown on the lower curve of Figure 6. This curve appears to have the same general characteristics as does the curve for the response of the original distributed power amplifier. Both response curves fall off at the lower audio frequencies because of degeneration of the screen grids of the amplifier tubes.

The power gain for the modified amplifier is lower because it takes a greater grid power to develop the same

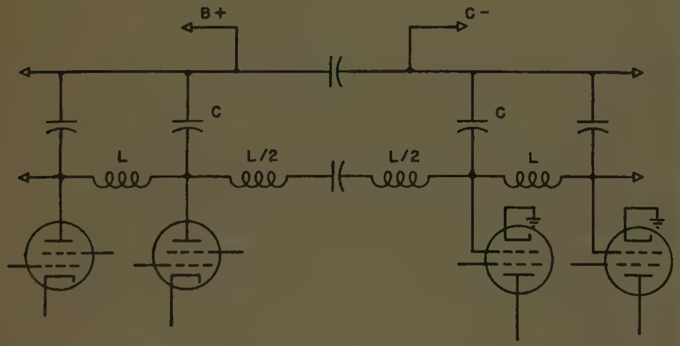


Figure 7. Two distributed amplifiers cascaded without the use of terminating resistors

Figure 8. Distributed voltage amplifier using 6AC7 tubes

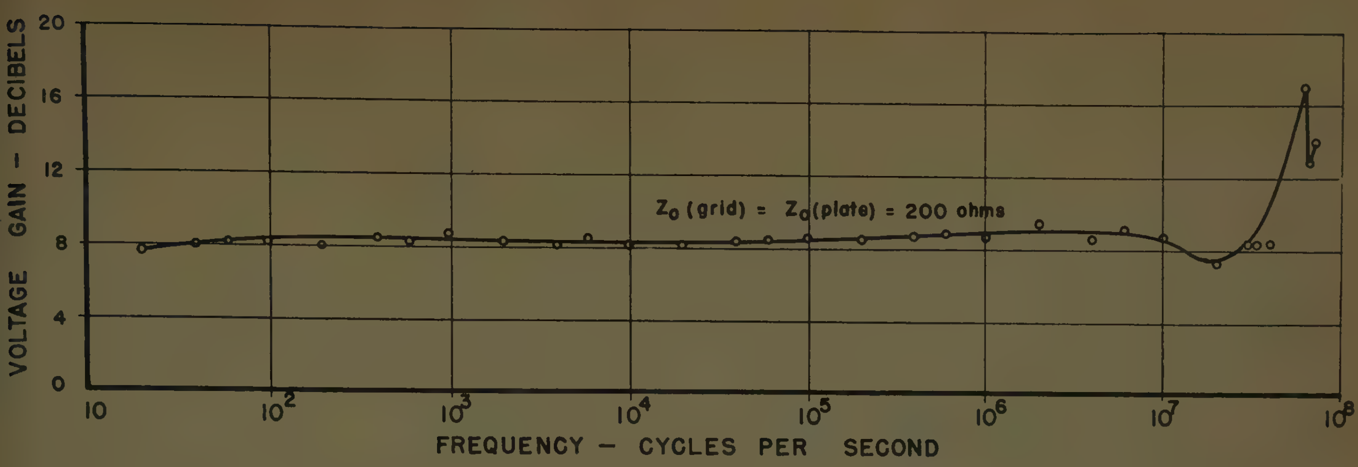


Figure 9. The frequency response for the voltage amplifier is flat within one decibel from 20 cycles to 30 megacycles

input voltage with the new lower grid-line impedance. To test the phase-shift distortion of the power amplifier, a square wave with a 10-volt maximum value and a frequency of 100,000 cycles was applied to the input. The output at both plate terminating resistors was an amplified square wave that showed very slight rounding on the top and no loss of straightness on the edges. A test was made to determine the maximum power output attainable with the amplifier. With a grid bias of 45 volts, a plate voltage of 600 volts, and a grid input of 40 volts, the output was 85 volts at four megacycles. This corresponds to 15 watts output, which should be sufficient to apply modulation to the grid of a television transmitter as well as other power applications.

The same tests were made on this modified amplifier for phase distortion and nonlinear distortion. The results appeared approximately the same as for the original power amplifier. It seems that this modified amplifier with the grid and plate line impedances not equal will work equally well. This is quite convenient, for now the Z_0 of the plate line need not be limited by the high input capacity of the grids of the amplifier tubes. Also, the distributed amplifiers may be cascaded more easily.

Figure 7 is a simplified schematic diagram showing how it is possible to cascade two distributed amplifiers without using terminating resistors. Either large capacitors or small capacitor by-passed glow tubes may be used in order to isolate the d-c circuits of the two stages to obtain the desired performance.

The Distributed Voltage Amplifier. There is a need now for a distributed voltage amplifier to give the voltage necessary to drive these distributed power amplifiers. For these voltage amplifiers, there is a definite best gain per stage of amplification. This occurs because some of the gain is obtained by adding within the stage and some of it is obtained by multiplying between stages. As shown in computations in Appendix II, the best gain for each stage is ϵ, the base of natural logarithms. If the stage gain is higher than this, there will be too many tubes per stage to be economical. Lower than this, the stage gain will be so low that too many stages will be required to obtain the desired over-all gain.

The inductance, capacitance, cutoff frequency, and impedance for the plate and grid lines may be computed in the same manner as for the power amplifier. Having the value of Z_0, the gain of each tube in the voltage amplifier is

$$A = g_m Z_0/2 \tag{12}$$

It is possible now to determine the number of tubes which are required in one stage in order to get a gain of ϵ, numerically 2.72.

One virtue of the distributed amplifier is that it can operate with tube gains of less than unity and still have an over-all stage gain greater than unity. Under stringent requirements of frequency response these low values of Z_0 must be used with their accompanying low gain per tube.

The distributed voltage amplifier which was constructed to test the operation of this type of amplifier is shown in Figure 8. The values of the basic components follow: Z_0 of both lines 200 ohms, C is 25 micromicrofarads, L is 1.15 microhenrys, and the cutoff frequency is 55 megacycles. For the given Z_0, the cutoff frequency could have been made much higher, as the input capacity of the *6AC7* tubes used is only 11 micromicrofarads. The frequency

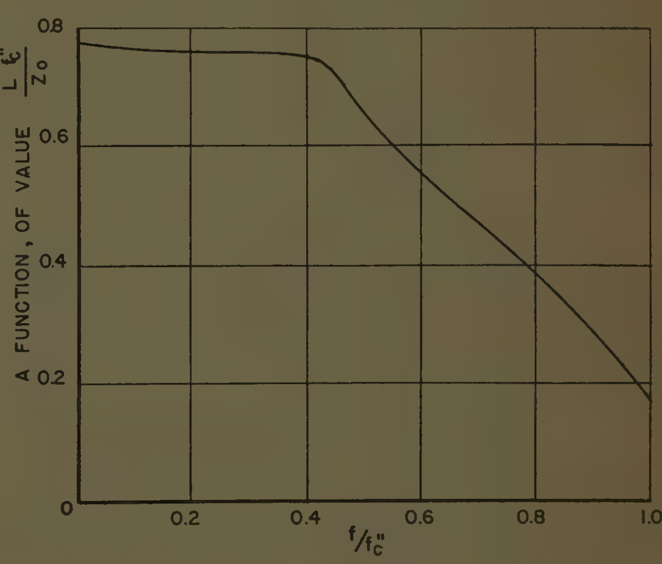


Figure 10. Plot of the function $L = \frac{\pi Z_0}{48 f_c''}\left[12 - \pi^2 \frac{(f)^2}{(f_c'')}\right]$ required to make $\beta = k'$ (frequency)

was kept low for testing by increasing the capacitance.

As the voltage gain for each tube is

$$A = g_m Z_0/2 = (9{,}000 \times 10^{-6})(200)/2 = 0.9 \quad (12)$$

it takes three tubes to give an over-all gain of 2.7.

The schematic wiring diagram for this amplifier is essentially as given in Figure 3 except that the screen grids of the *6AC7*'s are connected to by-passed *VR 150–30* voltage-regulating tubes. This eliminates screen degeneration and allows the frequency response to be flat back to zero cycles per second.

Figure 9 shows the frequency response for the voltage amplifier. The response is flat within one decibel from 20 cycles to 30 megacycles. The shape of the curve is in close agreement with the curve for the characteristic impedance Z_0 of an m-derived half-section terminated filter with an m of 0.6. This is as expected for the gain is proportional to Z_0. The frequency response over the operating band was observed in the same manner as for the power amplifier. A few additional points were taken around 60 megacycles using a tuned line oscillator as the signal source. These show a high value of amplification as would be expected from the curve of Z_0 for the lines in Figure 2.

The voltage gain appears to have a value of 2.5 which is quite close to the calculated value of 2.7. The gain may be varied over wide limits by varying the battery bias as the transconductance g_m of the tubes varies with the bias.

CONCLUSIONS

THREE important conclusions may be obtained from the investigations made on the distributed amplifier:

1. Satisfactory distributed amplifiers may be constructed utilizing the basic design developed here. The distributed power and voltage amplifiers have a frequency response over the band from a few cycles to 20 or 30 megacycles; however, this is not the upper frequency limit attainable with amplifiers of this type.

2. To improve the distributed amplifier further, tubes with their plate and grid connections on opposite ends of the tubes are needed. These tubes will need short grid and plate leads. In addition, they should have as high transconductance and as low shunt capacitance as possible.

3. The distributed amplifier is easily constructed, is stable in operation, and seems well adapted to practical use.

Appendix I

Object: To determine the expression for the inductance of a coil, in terms of frequency, that will occur under the condition that β is a linear function of frequency. As developed in texts on filters

$$\beta = \cos^{-1}(1 - \omega^2 LC/2) \quad (9)$$

This function is plotted in Figure 4.

Solving equation 9 for the inductance in terms of frequency

$$\cos\beta = 1 - 2\pi^2 f^2 LC \quad (13)$$

$$L = \frac{1 - \cos\beta}{2\pi^2 f^2 C} \quad (14)$$

But we have demanded that β be a linear function of frequency.

$$\beta = K'f \quad (8)$$

K may be determined by the boundary condition at f_c''.

$$\beta_{(\text{cut-off})} = \pi = K'f_c'' \quad (15)$$

$$K' = \pi/f_c'' \quad (16)$$

Substituting equation 16 in equation 14,

$$L = \frac{1 - \cos\pi\,(f/f_c'')}{2\pi^2 f^2 C} \quad (17)$$

Applying the series expansion of a cosine function,

$$\cos\pi f/f_c'' = 1 - \frac{\pi^2(f/f_c'')^2}{2!} + \frac{\pi^4(f/f_c'')^4}{4!} - \ldots \frac{\pi^n(f/f_c'')^n}{n!} \quad (18)$$

Dropping all terms past $n = 4$,

$$L = \frac{1 - \left[1 - \frac{\pi^2(f/f_c'')^2}{2} - \frac{\pi^4(f/f_c'')^4}{24}\right]}{2\pi^2 f^2 C} \quad (19)$$

Simplifying,

$$L = \frac{1}{48 f_c''^2 C}\left[12 - \pi^2\left(\frac{f}{f_c''}\right)^2\right] \quad (20)$$

The value for the shunt capacitance of a low-pass constant-k filter,

$$C = 1/\pi f_c'' Z_0 \quad (9)$$

Substitute this in equation 20,

$$L = \frac{\pi Z_0}{48 f_c''}\left[12 - \pi^2\left(\frac{f}{f_c''}\right)^2\right] \quad (23)$$

This function, rearranged slightly, is plotted in Figure 10.

Appendix II

Object: To prove that the most economical stage gain is ϵ. Designate the values used below by these symbols:

A = the voltage gain per tube.
r = the number of tubes per stage.
Ar = the stage gain.
n = the number of stages, a positive integer.
N = the total number of tubes.

We make the assumption that n has a continuously variable value for the following differentiation; keeping in mind, however, that it may only have positive integer values. Two basic equations may be written:

$V = (Ar)^n$ The over-all voltage gain (24)

$N = rn$ The total number of tubes (25)

The value of Ar, the stage gain, shall be found that gives the maximum over-all voltage gain for a given number of tubes. Taking the value for r in equation 25 and substituting in equation 24,

$$V = (AN/n)^n \quad (26)$$

Taking the derivative of this and setting it equal to zero,

$$dV/dn = n(AN/n)^{n-1}(-AN/n^2) + (AN/n)^n \ln(AN/n) = 0 \quad (27)$$

Simplifying,

$$dV/dn = n(AN/n)^n(-1/n) + (AN/n)^n \ln(AN/n) = 0 \quad (28)$$

Factoring,

$$-1 + \ln(AN/n) = 0; \text{ or } \ln(AN/n) = 1; \text{ or } AN/n = \epsilon \quad (29)$$

Substituting r back in, it may be seen that the maximum value of V is attained when the stage gain is

$$Ar = \epsilon = 2.718 \quad (30)$$

Main Power Transformers for Generating Stations

N. E. DILLOW
MEMBER AIEE

J. W. BUTLER
FELLOW AIEE

TODAY many factors, including cooling, rating, and number of phases, affect the selection of the main power transformer. The types of transformer cooling now available are: type *OA*, self-cooled; type *OW*, water-cooled; type *OA/FA*, self-cooled/forced-air-cooled; type *OA/FA/FA*, self-cooled/forced-air-cooled; type *FOA*, forced-oil-air-cooled; and type *FOW*, forced-oil-water-cooled. The choice of the method of cooling for a transformer may depend on consideration of load cycle requirements, first cost, losses, reactance, installation cost, maintenance cost, shipping limitation, and other factors.

The economic approach to the choice of the type of cooling can best be illustrated by an example. For consideration, assume it is desired to choose the transformer for use with a 60,000/66,000-kw preferred-standard turbogenerator to be installed in a conventional unit plan; that is, the generator and transformer are to be in series with no switching at the generator voltage. Further, let it be assumed the transformer maximum rating is 82,500 kva and the transmission voltage is 138 kv. Table I indicates an economic comparison on an annual cost basis of the types of cooling. For this example typical values are used for demand charge of $140 per kilowatt, incremental energy charge at 2.5 mils per kilowatt-hour, and annual carrying charge at ten per cent.

A basic loading of 70,000 kva is presupposed as the usual operating level for the unit. This is the loading many operators consider reasonable for a 60,000/66,000-kw machine. This does not preclude the possibility that occasionally system conditions will make it necessary to operate the unit at higher loadings, especially during emergency conditions, but it is not considered good economics to base an evaluation on emergency or abnormal loading conditions. It appears, therefore, rational to use a basic loading for the evaluation rather than the maximum transformer rating for the generating station application. Hence, the example of Table I can serve as a guide for comparing the economics of the types of cooling available.

The choice of the transformer size in kilovolt-amperes depends on the interpretation given to the various ratings and intended loadings in service of the boiler, turbine, generator, and transformer. Since the investment in transformer capacity is low relative to that in steam-generating equipment and turbogenerators, it does not appear to be good judgment to be unnecessarily conservative in the choice of the main power transformer size. Consideration of the problem will indicate that it appears reasonable to consider the maximum capabilities of the generator when choosing the transformer rating. Practically all steam-turbine-driven generators 15,000 kva and above are now hydrogen-cooled and rated at one-half pound hydrogen pressure with capabilities of 115 per cent at 15-pound hydrogen pressure. Experience has indicated that selecting a transformer size based on the 15-pound capability of the generator has proved to be a sound selection.

Digest of paper 50-128, "The Choice of Main Power Transformers for Generating Stations," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

N. E. Dillow is with the General Electric Company, Schenectady, N. Y., and J. W. Butler is with the General Electric Company, Pittsfield, Mass.

The choice of the rating of the transformer can be predicted on economic factors previously considered. Without regard to maximum loading requirements, the economics of the choice in rating can be illustrated by a comparison similar to that in Table I. Such a comparison would be based on the same basic loading for the generator, and will indicate that the total cost is relatively independent of the rating for the range which would be considered. With all factors evaluated, such as the reduced reactance at the normal loading of the generator and the turbogenerator capabilities, a small increase in annual cost can be justified. Therefore, it appears rational to choose a transformer whose maximum rating matches the 15-pound hydrogen rating of the generator.

The choice of a 3-phase unit or three or four single-phase units for the main power transformer is a question of use preference. However, because of the excellent service record, lower cost, lower losses, lower exciting current, and lower installation expense of 3-phase units, the trend of the industry is toward 3-phase main power transformers.

Table I. Example of Economic Comparison for Choice of Type of Transformer Cooling

Type of Cooling	*OA-T*	*OA/FA-T*	*OA/FA/FA-T*	*FOA-T*
Rating, kva*	82,500	66,000/82,500	49,500/82,500	82,500
Impedance, %	7.5 at 82.5 mva	7.5 at 66 mva	7.5 at 49.5 mva	11.25 at 82.5 mva
Exciting current, %	2.9 at 70 mva	2.4 at 70 mva	2.0 at 70 mva	2.2 at 70 mva
Basic loading, kva	70,000	70,000	70,000	70,000
First cost†	$215,000	$192,000	$163,000	$148,000
No-load loss, kw	163	139	113	125
Load loss at 70 mva, kw	150	206	300	280
Fans and/or pump loss, kw		9	26	25
Total kw loss	313	354	439	430
I^2X loss, kvar	4,460	5,570	7,430	6,680
Excitation loss, kvar	2,030	1,680	1,400	1,540
Total kvar loss	6,490	7,250	8,830	8,220
Transformer carrying charge at 10%	$21,500	$19,200	$16,300	$14,800
Capacity or demand change at $140/kw at 10%	$ 4,380	$ 4,960	$ 6,150	$ 6,020
Energy loss at 2.5 mils				
No-load loss for 8,400 hrs	$ 3,420	$ 2,920	$ 2,375	$ 2,625
Load loss for 5,977 hrs (80% load factor with 68% equivalent hrs)	$ 2,250	$ 3,090	$ 4,500	$ 4,200
Kvar loss at $6/kvar at 10% ¶	$ 3,900	$ 4,350	$ 5,300	$ 4,930
Total transformer annual cost (10%)	$35,450	$34,520	$34,625	$32,575

* Transformer rating considered for use with 60,000/66,000-kw preferred standard turbogenerator.

† Transformer cost based on 3-phase 60-cycle 138,000 Grd.Y/13,200 (115-kv insulation class) with four 2½ per cent taps.

¶ Reactive kilovolt-ampere loss evaluation is optional depending on system conditions.

Economic Aspects of Large Power Transformers

C. M. SHORT
MEMBER AIEE

W. G. HART
ASSOCIATE AIEE

FIXED RATES and rising costs of construction and operation have posed a financial problem for many electrical utilities. Because transformers represent 25 to 40 per cent of a utility's expenditure for electric equipment and nearly one-half of this capacity is in large units used for transmission of bulk power, proper selection and application of large power transformers offers one avenue for a substantial reduction in the total system investment.

The four most important changes affecting large power transformer application practice which should be considered for the purpose of reducing capital costs are: use of 3-phase instead of single-phase transformers; use of forced-air and forced-oil cooling; use of reduced insulation on solidly grounded systems; and omission of taps on central station step-up banks. Experience, although covering a relatively short period, shows that these changes are technically sound and offer a means of reducing capital costs without any apparent decrease in reliability.

The problem of providing a spare transformer has often influenced the decision regarding the use of single-phase instead of 3-phase units and this is a factor which must be evaluated for each particular installation. Because of improvements made in basic design, reliability of power transformers has increased steadily through the years until today the calculated risk of failure is extremely small. In recognition of this, some utilities have found it entirely feasible to omit the spare transformer.

To the designer of a modern station there are available many types of transformer cooling, and selection can usually be made from four commonly used types described as follows: single-rated self-cooled (type OA); double-rated self-cooled/forced-air-cooled (type OA/FA); triple-rated self-cooled/forced-air-cooled/forced-air-cooled (type OA/FA/FA); single-rated forced-oil-cooled (type FOA).

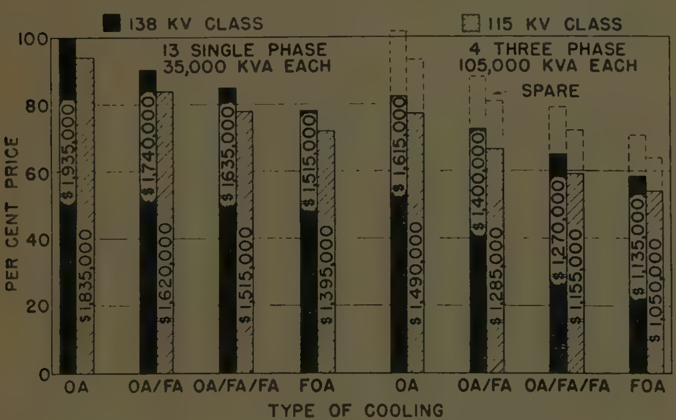


Figure 1. Installed costs of 138-kv transformers, four 105,000-kva banks. The dotted outline indicates the cost of a 3-phase spare and is shown for comparative purposes only and is not included in the cost figures

Reductions in floor area, weight, and first cost are realized with forced cooling. As physical size is decreased, core loss becomes less while total losses and impedance increase as shown in the following table:

Type	Core Loss	Total Loss	Impedance	Floor Area	Weight
OA	1.00	1.00	1.00	1.00	1.00
OA/FA	0.90	1.25	1.25	0.90	0.90
OA/FA/FA	0.85	1.67	1.67	1.20	0.80
FOA	0.80	1.50	1.50	0.70	0.75

Because of different amounts of copper used, power and energy losses will vary for each type. A loading schedule resulting in a high loss factor favors self-cooled transformers and low loss factor favors forced cooling. In comparing energy losses it is important that the load schedule and price of fuel throughout the expected usable life be estimated with reasonable accuracy. Both of these are subject to variations over which the engineer has no control and for that reason it is unwise to pay a high premium for more efficient equipment unless the margin of expected saving is sufficiently great to allow for reasonable changes in load factor and price of fuel.

The higher reactance of forced-cooled transformers also entails losses which must be evaluated. Low reactance normally is desirable because this increases transient stability limits, reduces reactive losses, and contributes to better voltage regulation. If low reactance is necessary from a stability consideration, it usually is less expensive to obtain it in the transformer than in the generator or to build a line with less reactance. Thus, selection of the type of cooling is entirely an economic problem in which the initial investment saving must be balanced against the value placed on reactance and the cost of kilowatt and kilovar losses.

Recent years have seen a growing trend toward the use of a lower insulation class on grounded systems. Lowering of insulation levels has been made possible because reliability of the modern lightning arrester has increased to the point where it can be depended upon to hold lightning and other overvoltage stresses below a definite and predetermined value. Operating experience shows that a reduction in impulse insulation levels is feasible and consistent with good over-all design.

Savings to be realized in a 4-unit 400-megawatt generating station by adopting one or more of the money-saving features thus far discussed is illustrated in Figure 1. The dotted outline indicating the cost of a 3-phase spare is shown for comparative purposes only.

Digest of paper 50-167, "Engineering and Economic Considerations Applicable to Large Power Transformer Installations," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Not scheduled for publication in AIEE *Transactions*.

C. M. Short is with the Department of Water and Power, The City of Los Angeles, Calif., and **W. G. Hart** is with the General Electric Company, Los Angeles, Calif.

Solderless Commutator Joints for Railway Traction Armatures

J. R. REED
MEMBER AIEE

A solderless commutator joint has been developed for use in armatures of high-speed diesel-electric motors which may rise to temperatures above 600 degrees Fahrenheit to eliminate the failures which occur when soldered joints are used. By silver-plating the lead section of the armature coils and the inside surface of the riser slot and winding the armature conventionally with the special coils, a machine which performed satisfactorily under standard working conditions was obtained.

THE ADVENT of the diesel-electric locomotive and its rapid large-scale acceptance by the railroads of the United States has brought to the fore many problems for which solutions must be found. Among the problems related to this tremendous increase in heavy d-c electric traction equipment is that of adequate joints between coil leads and commutator bars in motors subjected to severe operating conditions. This is a problem of long standing in motors operated at high temperatures, but it has become much more acute with the development and use of insulating materials that will withstand more and more heat. The first substantial increase in permissible operating temperatures of such equipment was brought about a number of years ago by the introduction of full Class-*B* insulation to replace the then standard Class-*A*, or composite, insulation. This permissible temperature now has been further increased by the acceptance of Class-*H* (Silicone) insulation as standard in certain types of traction motors.

For traction motors operated at normal temperatures, the conventional solder joints between coil leads and commutator bar made with lead-tin alloys have proved satisfactory when an area large enough to provide a satisfactory conductivity of the joint is available. However, as operating temperatures have increased in value and design restrictions have decreased the available space for the commutator joint, the factor of safety thus afforded has been reduced to the danger point.

As noted, the chief source of difficulty in commutator joints is high temperature of operation. All lead-tin solders between $2^1/_2$ and 85 per cent lead with the single exception of the eutectic alloy (37 per cent lead) have what is known as a plastic range. This is a range of temperature over which the alloy is in the form of a mush or suspension of unmelted crystals in molten metal. This is shown graphically in the lead-tin constitution diagram,[2] Figure 1. At temperatures above this range the alloy is completely liquid, and at temperatures below it the alloy is completely solid. The eutectic alloy melts abruptly at the lower limit of this range which is constant for all alloys of these two metals within the limits mentioned. This temperature is 361 degrees Fahrenheit. It is at this temperature that these lead-tin alloys soften and begin to flow; and thus, it is at this temperature that the mechanical protection of any lead-tin solder is lost or greatly impaired regardless of the "hardness" of the solder.

In armature work where full Class-*BBB* windings are used with a permissible operating temperature up to, or even in excess of, 300 degrees Fahrenheit, it is obvious that a solder which gives little or no protection above 361 degrees Fahrenheit leaves a negligible factor of safety for overload or other unusual conditions. This situation is further aggravated by the possibility of a high-resistance electrical joint which will cause still additional heat to be generated in the contact area of the solder.

For this reason, it has been customary to use solders with higher melting points for this class of work. Unfortunately, however, such solders are very limited in both availability and desirable properties. The most satisfactory of these has been a solder consisting of pure tin or 95 per cent tin and 5 per cent antimony. Both of these solders give protection to approximately 450 degrees Fahrenheit and are quite satisfactory for use where temperatures never exceed this limit. With the pure tin the plastic range is entirely eliminated, and in the case of the tin-antimony alloy it is reduced to a range of about five degrees Fahrenheit. Because of the desirability of some plastic

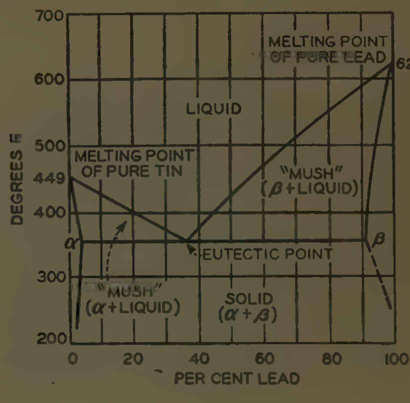


Figure 1. Lead-tin constitution diagram showing the temperature range over which the alloy has a suspension of unmelted crystals in molten metal

The eutectic alloy, 37 per cent lead, has no plastic range but melts abruptly at 361 degrees Fahrenheit

Full text of paper 50-100, "Solderless Commutator Joints for High-Temperature Operation of Railway Traction Armature," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

J. R. Reed is resident engineer in Pasadena, Calif., of the National Electric Coil Company of Columbus, Ohio.

The author expresses his indebtedness to the Atchison, Topeka, and Santa Fe Railway for their assistance and general supervision, for making possible the investigation and road testing, and for permission to submit this paper.

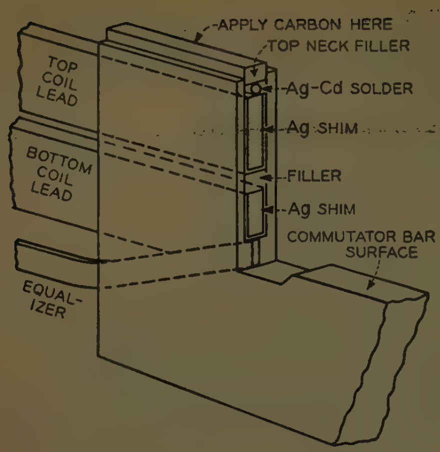


Figure 2. Sketch showing the use of the silver shim to tighten the coil leads in the commutator risers

The silver-cadmium solder is used to bond the top filler to the commutator risers

range for ease of working, the tin-antimony alloy is most popular where hand soldering is employed. In addition, the antimony is thought to give a solder which will alloy to a greater extent with the copper being soldered, thus giving a better joint. Pure tin is used principally in solder-pot applications. These are the two solders most widely used on heavy high-speed diesel-electric traction armatures.

Even though pure tin or tin-antimony solders used with care in either hand soldering or pot soldering give a joint which is reasonably satisfactory for armatures insulated with standard Class-*B* components and operated at normal temperatures, they are not adequate for armatures insulated with Class-*H* (Silicone) components and operated at the still higher temperatures consistent with this insulation.

At present, temperatures are often attained in the operation of these armatures which exceed the melting point of this type of solder. In fact, well over 50 per cent of all armatures returned to the shops of at least one large railway have high-resistance commutator solder joint readings, and over 20 per cent require resoldering. Because of this, much work has been done to develop a solder with a still higher melting point. A number of these solders have been produced and used, particularly during the recent war when the use of tin was restricted; but, for a number of reasons, they have not been satisfactory.

Most of the high-temperature solders are primarily high-lead solders. An analysis of one solder in this class shows lead, 97.50 per cent; silver, 1.50 per cent; bismuth, 0.50 per cent; antimony, 0.50 per cent. Another has the following constituents: lead, 97.25 per cent; silver, 2.50 per cent; copper, 0.25 per cent.[3] The first of these has a plastic range of 540 to 548 degrees Fahrenheit, and the second has a plastic range of 550 to 580 degrees Fahrenheit. Although the melting points of these solders indicate that, from the standpoint of temperature, they are satisfactory for most applications, they still do not leave much factor of safety under present operating conditions.

In practice, however, this type of solder is extremely difficult to use with consistently satisfactory results. This is primarily because of the poor spread factor, characteristic of high-lead solders. The spread factor is defined as the area in square centimeters that will be covered on clean copper when one gram of the solder is melted completely. This factor for the high-lead solders averages only about one-fifth that of the high-tin solders. For this reason, these solders are extremely difficult to flow into contacts where there is even a reasonably tight fit, such as is the case with high-speed traction armatures. However, they can be and, in fact, are being used with good results in certain types of d-c armatures where space requirements and general design are more liberal. They are also used with good results in soldering steel-wire coil retaining bands.

In the case of a particular high-speed diesel-electric armature, the electrical conductivity of the commutator joint is only about 1.5 times that of the armature bar, even when a perfect solder job has been accomplished with this type of solder. In practice, however, it has not been possible to obtain consistent soldering results which will give assurance of more than half of this amount, and even this requires careful attention to all details of cleaning, fluxing, and soldering operations with high-lead solders. For this reason, it is not possible with these high-temperature solders to obtain connections in the high-speed traction armatures under discussion which will be consistently low in electrical resistance. As a consequence of this, heat in excess of the operating heat of the armature is liberated in the very joint which is particularly vulnerable to the effects of the high temperature; and a considerable part, if not all, of the advantage of the higher melting points of the solders is thus nullified. Furthermore, these solders are subject to oxidation as the temperature is increased, and the tendency is to produce joints eventually of high electrical resistance. In severe operation this brings on a vicious circle of events.

Although the use of other solders in the high-temperature range has been attempted, this has been without much success up to the present time. This is primarily because of the difficulty of getting an alloy which will flow readily into the small spaces involved and adhere properly to the copper bars with fluxes that are available for soldering operations on electric apparatus at these temperatures.

Tests were made with low-temperature brazing to determine if this might not possibly be a satisfactory solution to the problem. This was ruled out, however, by a number of factors. Chief among these is that the temperatures involved are destructive to the commutator insulation where such a sizable joint must be made very deep in the commutator bar, as is the case with short riser bars characteristic of high-speed traction armatures where equalizer coils must often be connected actually below the level of the commutator surface. In addition to this, the work involved in milling out these connections, even if it were feasible, would so increase the cost of a subsequent rewind that this alone would make the method prohibitive.

SILVER-PLATED JOINTS

With brazing thus ruled out, and since no suitable solder in the temperature range above 600 degrees Fahrenheit and below 700, or possibly 750, degrees Fahrenheit was available, tests were made to determine if a suitable soft joint could be obtained by the use of silver plating and the complete elimination of a fused connection. With this in mind, two sets of special armature coils were manufactured incorporating a heavy silver-plated lead section in place of the then standard tinned leads. Two

armatures were prepared for these coils, and the commutator risers were thoroughly cleaned of all residual solder and tinning by means of a pneumatic disk sander with fine grit. Care was taken to preserve as nearly as possible the original surface of the copper bar and to avoid an irregular surface which might interfere later with the plane surface contact which it was hoped would be obtained.

After the risers were thoroughly cleaned in this manner, the inside surfaces of the riser slot were silver-plated by means of a portable silver-plating apparatus using controlled direct current and a silver cyanide electrolyte. The current was controlled by means of surface pressure and voltage so that, as nearly as possible, a bright plate was obtained. The silver was built up to a thickness of approximately 0.0005 inch and the commutator thoroughly cleaned with pure water and then baked and tested for bar-to-bar resistance. Satisfactory cleaning was achieved with the first attempt.

Following this preliminary preparation, the armature was wound in conventional manner with the special coils with the exception that the commutator risers were blocked ahead of the leads being laid, and the connections were shimmed to produce a very tight circle of the risers. The material used for this shimming was fine silver shim stock rolled to a thickness of 0.003 inch and inserted in approximately every fourth or fifth riser as was needed to maintain the tight fit. The silver was used in the annealed form and was inserted as a U-shaped piece placed around the coil lead as it was driven into place in the commutator riser, as shown in Figure 2. The leads were driven into place as tightly as possible without causing appreciable upsetting of the copper. No shims were used with the equalizer winding, and these leads were actually upset into the bottom of the riser slots so as to produce a tight fit without shims. This was possible because of the relative difference in the dimensions of the equalizer leads as compared to the main coil leads and their location at the bottom of the slots.

As the winding progressed, first the equalizers and then the bottom main coil leads were "mudded in" with inorganic-filled Silicone compound. This material was used to fill completely the space back of the risers to eliminate the possibility of varnish getting into the joint in subsequent impregnation. Finally, as the top coils were laid as described, the remaining space behind the risers and the spaces at the ends of the cores were filled with inorganic-filled Silicone compound and the armatures hot-banded and wedged.

After checking the armatures for resistance in the standard manner, the remaining space in the riser slots above the top coil leads was filled in for mechanical reasons and to present a smooth contour. In the first armature this was done by brazing a copper filler into the opening with a phosphorous silver alloy material. However, as previously pointed out, this introduced the rather serious problem of stripping the armature for subsequent rewinding, and although this has not yet been done, it is evident that a softer filler would be of considerable advantage from this standpoint. For this reason, the second armature was finished by soldering the top filler into the risers with a special alloy consisting of 95 per cent cadmium and 5 per cent silver, and having a melting point between 640 and 740 degrees Fahrenheit. This solder was heated by incandescent carbon applied from the top under pressure and was fluxed with an acid-type flux used very sparingly. Actually, a small piece of the soldering alloy was placed in the slot under the filler which was deep enough to extend above the top of the risers. The carbon was applied to this filler and held until the solder melted and the filler settled into its place (see Figure 2). The results obtained in this way were very satisfactory and produced a mechanically strong bond at the top of the risers to prevent radial movement of the coil leads. The fillers could still be driven out much as the standard soldered fillers and did not require milling or sawing as did the brazed fillers. A simple jig and carbon holder was arranged so that very little time was required for this operation.

Both armatures were vacuum pressure impregnated in the usual manner with the exception that special precaution was taken to prevent the varnish level in the tanks from coming up over the risers during the process. Final tests were completed and the resistance readings, indicating the relative conductivities of the commutator connections, showed them to be completely uniform and fully as low as the best of the solder jobs which were being tested with the same equipment.

RESULTS OF ROAD TESTS

THE two armatures were placed in different high-speed passenger locomotives—the most severe application available. Both armatures were returned to the shop after approximately 60,000 miles, at which time they were put through the regular shop tests. Both armatures were checked especially to determine if there had been any changes in the commutator joints. Resistances were checked and found to be the same as when first applied and completely uniform with no high readings. After routine cleaning and checking, the armatures were again put out

Figure 3. Bearing failure which allowed the armature to rub on the pole pieces and wreck itself

The commutator risers were not destroyed and could be examined closely to see the effect of the high heat on the joint

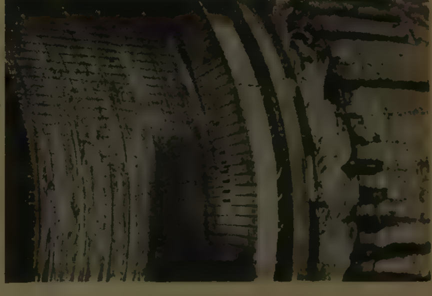


Figure 4. Close-up of commutator risers of the armature shown in Figure 3

Even though commutator temperature was raised to 700 degrees Fahrenheit, no damage was done to the riser connections

into the same service as before. The first armature to be rewound has not been in the shop since this first time and now has a mileage of more than 300,000 miles.

The second armature, however, was returned again after an additional 50,000 miles when the second locomotive to which it had been applied was in the shop for an annual overhaul. The armature was again checked carefully, and all resistance readings were found to be excellent and uniform, indicating that there had been no deterioration in the conductivity of the riser connections. There was no evidence of any excessive or localized heating as is evident in a majority of soldered armatures operated under the same conditions, even though they may not have failed. After routine cleaning and checking and re-impregnation, the armature was again placed in service on a similar locomotive where it remained in service for an additional 95,000 miles. After this additional mileage, it was returned to the shop following a complete bearing failure which allowed the armature to drag on the pole pieces and wreck itself, as is shown in Figures 3 and 4. This failure, after 206,000 miles of severe service, was not in any way the result of a winding failure, but rather caused by a mechanical failure.

Fortunately, the commutator risers were not destroyed by the failure and were left in excellent condition for detailed inspection and study. At the time of the failure, the temperature of the commutator was in excess of 700 degrees Fahrenheit as was evidenced by the fact that the cadmium-silver solder in the top fillers had melted and run. All of the external varnish had been charred or entirely burned out. The glass-base bakelite wedges had been charred or entirely burned out. In spite of this, as was to be expected, the riser connections showed no signs of damage from the heat. There had not been any movement of the bars in the risers even at the time of failure, though the coils had been thrown from the slots in about one-fourth of the armature and had dragged on the pole pieces.

After external inspection, the coils were cut off behind the risers, and the risers themselves carefully stripped to study the nature and condition of the contact. It was found that there had been some cold welding of the silver surfaces in all of the slots, while some, especially on the equalizer coils,[4] had considerable cold welding. This latter was probably due to the tighter fit of the equalizers caused by the upsetting of the copper during winding. This caused a much higher contact pressure in the constricted bottom portion of the riser slot than was obtained in the less restricted upper portions of the slots where the coils were merely wedged tightly. Some of the equalizer leads were welded so tightly that they required sawing to remove them from the slots.

There was only slight evidence of oxidation of the contact surfaces, and in no case was there any evidence of contact burning as so frequently takes place in soldered connections. There was considerable varnish in many of the contacts. This was probably due to capillary action during impregnation, by which the varnish filled the open spaces in many slots, leaving free only those surfaces that were actually in solid contact. This condition should be prevented or at least minimized by more care in sealing behind the commutator before impregnation. It may possibly have been caused by improper care in one of the impregnations to which the armature was subjected during its life, and greater care in this respect might also be indicated. Actually, the presence of a varnish film in a portion of the contact area is of little consequence, because conductivity equivalent to that of the armature bar can be maintained in the commutator contact if over 90 per cent of the available area is unused. In other words, with silver-to-silver contact, the designed factor of safety of the connection with respect to electrical conductivity is about 15 as compared to about 1.5 for a perfect solder contact.

In addition to this much greater factor of safety is the fact that silver oxide between silver surfaces breaks down to pure silver at temperatures above 356 degrees Fahrenheit.[5] For this reason, it seems that electrical conductivity of the silver joint would be improved materially following subjection to temperatures which would destroy a soldered contact. These higher temperatures, if they were attained, would also tend to destroy any varnish film that might be in the contact. It also seems that repeated oxidation and reduction of even a portion of the silver surfaces accelerates to a large degree the welding of the silver to a more solid contact. This, of course, would complement the natural cold welding characteristics of the silver which are also accelerated as the temperature is increased.

As a further practical test of this type of commutator connection, it is proposed that another ten armatures be wound in this manner and put into service under severe operating conditions as were these two. Certainly there will be refinements in technique to improve the contacts as well as to reduce the labor involved in making them. The use of new or rebuilt commutators manufactured with silver-plated riser slots in place of tinned slots would be a big step in this direction. However, even with the present methods described in this article it is expected that a definite saving can be shown in labor as compared with standard soldered joints.

On the basis of the preliminary tests which have been conducted, and on the basis of the performance of the two test armatures in actual road service, it seems safe to conclude that this method of making commutator connections, although a radical departure from accepted practice, offers a practical step toward the much needed solution to the problem of furnishing a satisfactory connection between commutator and coils for operation at temperatures above the limits of soldered joints in equipment which does not lend itself to the application of brazing. The problem, as stated in the beginning of this article, is becoming very acute as insulations are being adopted which will materially increase the temperature limits for traction armatures.

REFERENCES

1. *AIEE Standards No. 1*, Introduction. June 1947.

2. The Constitution of Lead-Tin Alloys, **D. Stockdale.** *Journal of the Institute of Metals* (London, England), volume 49, 1932, page 267.

3. Substitute Solders, **F. N. Rhines, W. A. Anderson.** *Metals and Alloys* (New York, N. Y.), November 1941, pages 704–11.

4. Silver in Industry (book), **Lawrence Addicks.** Reinhold Publishing Company, New York, N. Y., 1940. Page 197.

5. *Ibid.* Page 187.

Underground Hydroelectric Power Plants

PAUL E. GISIGER

UNDERGROUND hydroelectric powerhouses are becoming almost the rule, rather than the exception, for high-head developments in Europe, and even for medium- and low-head developments this type of plant is finding application in a number of instances.

While the thought of safety against war-borne destruction is undoubtedly a factor in promoting the underground location of generating equipment, it should be remembered that the first underground plant was built in 1910, when protection against bombing was of little concern. Under certain conditions an underground powerhouse may be the best choice for purely technical and economic reasons.

For the purpose of this article a plant is designated as underground when its turbines and generators are located below, or inside, the original earth or rock surface of the plant site. There are underground plants where the step-up transformers also are located underground adjacent to the generating equipment; in others, the transformers are located above ground in an outside switching station, with cables from generators to transformers.

The trend to the vertical shaft arrangement of generating units even for the highest-head Francis turbines and for Pelton turbines is working in favor of underground plants, because it reduces space requirements. This is true for the closed circuit ventilation of generators as well, because the problem of a fresh-air supply for an underground plant is greatly reduced.

In general, decided advantages from underground location may result when

1. Climatic conditions are very severe, because underground construction is not hampered or retarded by blizzards and snow drifts.
2. Space above ground is restricted, such as in narrow canyons, where underground location also results in more freedom in the location of tunnels and penstocks.
3. Alluvial valley bottoms present foundation difficulties, which may be avoided by locating the powerhouse inside the flank of the valley.

Digest of paper 50-186, "Underground Hydroelectric Power Plants," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

P. E. Gisiger is with the Companhia Brasileira Administradora de Servicos Tecnicos, Sao Paulo, Brazil.

An underground powerhouse naturally must be located in sound rock, and careful geologic investigation of the site is indispensable. In the layout of the powerhouse, safety against accidental flooding has to be considered. This is done sometimes by locating valves between penstocks and turbines in a separate cavern. It is also done by providing ample facilities for drainage into the tailrace of water which might enter the powerhouse.

In most underground powerhouses there is an air space left between walls and ceilings and the rock face to insure dryness of the inside rooms. Those air spaces can be used advantageously for ventilation purposes.

Power generally is taken out of underground stations with cables, whether transformers are located underground or above ground; there are several instances where 150-kv cables go from the powerhouse to an outside switchyard, and one powerhouse is now under construction in Switzerland where 220-kv transformers will be located underground. On the other hand, especially in some older installations, power is taken from generators to outside transformers in open bus bars. In most cases, the cable or bus tunnels are used also for ventilation, while a separate entrance tunnel is provided for personnel and equipment.

Generally it is not difficult to insure ample ventilation of an underground powerhouse, but care must be taken that fresh air reaches all vital spaces, like the control room.

Table I lists some representative underground hydroelectric plants.

Table I. Some Representative Underground Hydroelectric Power Plants

Plant	Country	Capacity, Installed or Prospective, Kilowatts	Gross Head, Feet	Turbines	Volume of Powerhouse Cavity: Net., Cu. Yds.	Volume of Powerhouse Cavity: Including Valve Rooms, etc., Cu. Yds.	Powerhouse Net, Cu. Yds. Per Kw	First Year of Operation
Porjus (original)	Sweden	60,000	183	8 Francis horizontal	35,000	41,000	0.58	1910
Brommat	France	186,000	855	6 Francis vertical	60,000	76,000	0.32	1932
Innertkirchen	Switzerland	210,000	2,235	5 Pelton vertical	59,000	79,000	0.28	1942
San Giacomo	Italy	200,000	2,140	3 Twin Pelton horizontal	37,000	42,000*	0.19	1948
Provvidenza	Italy	150,000	838	3 Francis horizontal	44,000	47,000†	0.29	1949
Lavey	Switzerland	72,000	130	3 Kaplan vertical				1950
Handeck II	Switzerland	114,000	1,518	4 Pelton vertical	39,000		0.34	1950
Harspranget	Sweden	377,000	346	4 Francis vertical				1951
Santa Massenza	Italy	284,000	1,505					
Monte Argento	Italy	66,000	164	3 Francis vertical	21,000	29,000¶	0.32	1952
Montorio	Italy	100,000	845	3 Francis vertical	29,000‡	30,000	0.29	
Verbano	Switzerland	100,000	973	4 Francis vertical	33,000		0.33‡	1952

* In addition: entrance tunnel, 54,000 cubic yards; bus shaft, 31,000 cubic yards; substation tunnels, 67,000 cubic yards.

† In addition: entrance tunnel, 29,000 cubic yards. ¶ In addition: entrance and bus tunnels, 3,600 cubic yards. ‡ Preliminary design.

Crossbar Tandem System

R. E. COLLIS
MEMBER AIEE

THE RAPID mechanization of the local telephone plant throughout the Bell System, together with the continuous expansion of subscriber dialing areas, has made necessary the development of an automatic tandem system having many new features not available in former tandem systems. This new system is known as crossbar tandem and is based on the crossbar system introduced in the late 1930's.

Chief among the important new features of crossbar tandem is its ability to act as means for interconnection of the various local systems, namely: manual, step-by-step, panel, Number 1 crossbar, and Number 5 crossbar. Provision is also made for operation with the various types of local and toll switchboards and for connections with the Number 4 type toll crossbar system.

Ample trunk capacity and a high degree of trunking flexibility, both as to the assignment of trunks on the switches and as to the number of trunks in a trunk group, are provided. The system operates at a much higher speed than former systems. Its inherent flexibility permits the ready incorporation of new features to meet new conditions as they arise.

Like the Number 1 crossbar system, the tandem crossbar system is of the common control type employing senders and markers. The senders receive and register the called code and number as pulsed from the originating office and, directed by the marker, translate this information into the proper type of pulsing required by the terminating office.

Figure 1 shows a front view of a 200-point crossbar switch. Any one of the 200 sets of contacts, called "crosspoints," can be closed by co-ordinate operation of a selecting magnet and a holding magnet. The contacts are held closed by the holding magnet alone. The selecting magnet is released as soon as the holding magnet is operated. A total of ten connections, one for each set of horizontal paths, can thus be established simultaneously. Each of the crosspoints may consist of from three to six separate make contacts, the number depending on the requirements of the circuit.

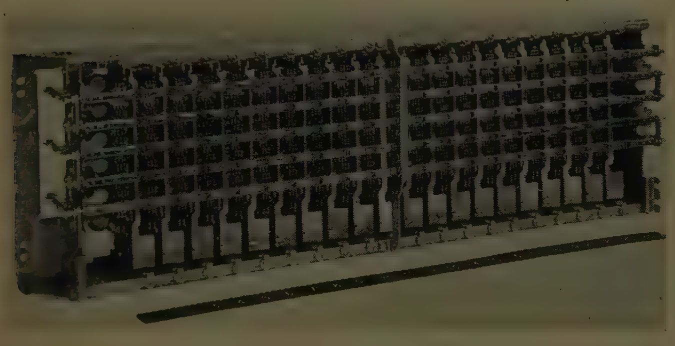


Figure 1. Front view of crossbar switch

The trunk switch frames consist almost entirely of crossbar switches interconnected in a primary-secondary arrangement. A group of these frames (maximum of 20) accommodates the incoming trunks (maximum of 160 per frame). A second group of switch frames (maximum of 20) accommodates the out-going trunks (maximum of 200 per frame).

The marker performs the functions of selecting an idle outgoing trunk to the proper office and also of selecting idle paths from the incoming trunk to the outgoing trunk through the switch frames. It then proceeds to set up the connection by operating, selecting, and holding magnets on the crossbar switches of the switch frames.

The principal power required by the crossbar tandem is 48 direct volts, which is used for the operation of practically all the signaling and transmission circuits. Several other sources of direct current are furnished for miscellaneous purposes. Individual frame filters are connected across the 48-volt power supply leads at the frames where noise-free battery supply is required for talking circuits.

The arrangements for maintenance of crossbar tandem are very similar to those in the Number 1 system. Routine test frames are provided for the senders and outgoing trunks. The incoming trunks can be tested from the trunk test boards of the originating offices and also by means of portable test sets at the tandem office. These test circuits apply marginal operations to the various circuits. The routine test frames perform these tests automatically and, if any trouble should be encountered, the tests are stopped and an alarm given to the maintenance force.

There are at present about 30 installations of crossbar tandem throughout the United States. Some of these are furnishing local tandem facilities in strictly step-by-step areas where the flexibility of the trunking arrangements is of particular advantage over the step-by-step tandem system. Installations in other areas are furnishing means for interconnecting the local manual, step-by-step, crossbar, and panel offices. A number of offices are primarily handling toll-terminating traffic where advantage is being taken of the ability of crossbar tandem to receive multi-frequency pulsing over long toll lines. This feature permits toll operators to complete calls through crossbar tandem in distant cities without the assistance of terminating operators.

An extensive development program is now in progress to incorporate new features which will still further enhance the usefulness of crossbar tandem in the rapid expansion of automatic switching in the Bell System.

Digest of paper 50-158, "Crossbar Tandem System," recommended by the AIEE Committee on Communication Switching Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

R. E. Collis is with Bell Telephone Laboratories, Inc., New York, N. Y.

Desert Measurements of Corona Loss

W. S. PETERSON
FELLOW AIEE

BRADLEY COZZENS
FELLOW AIEE

JOSEPH S. CARROLL
FELLOW AIEE

Conditions and losses measured on high-voltage transmission lines in some desert areas indicate that there are factors, yet unknown, which cause corona-loss values to occur at considerably lower voltages than would have been anticipated from previous tests in coastal areas. Here are presented the test methods and results of tests made on 287-kv test lines in the desert near Victorville, Calif.

THIS ARTICLE reports corona-loss measurements under desert conditions on 1.25-inch and 1.4-inch Hedernheim (*HH*) copper conductor and 1.4-inch aluminum-cable steel-reinforced (*ACSR*) conductor. From studies which have been conducted at Stanford University[2,3] and subsequent theoretical analysis,[4] it was indicated that 1.4-inch-diameter conductor would operate satisfactorily at 287 kv and that the segmental-type cable was more than sufficient for operation at 287 kv. This diameter initially had been established as a result of certain studies conducted on stranded-type cables.

Results of tests later conducted at Stanford[5] indicated that the 1.25-inch-diameter cable might operate satisfactorily at 287 kv with resultant reduction in capital investment in both conductor and towers. Contrary to this, however, observations on the desert in the vicinity of Victorville had indicated that, under certain climatic conditions not involving storms, corona was visible on 1.4-inch-diameter conductors in amounts appreciably more than would have been expected from the measured loss values or visual observations made at Stanford. Victorville is located at the base of a gradual slope on the northeastern side of the Sierra Madres at an elevation of approximately 2,800 feet. This phenomenon of unusual corona loss was not observed generally in the desert and did not exist at elevations between 3,000 and 4,000 feet. Little value would have been gained by testing 1.25-inch-diameter conductor at the Ryan High Voltage Laboratory since the question of desert surroundings had been interjected as an item affecting corona loss. It was of utmost importance, therefore, that tests be made on the desert in the vicinity where the unusual corona conditions had been observed.

The fundamental purposes of the tests, therefore, were first, to determine whether 1.25-inch-diameter segmental cable could be utilized satisfactorily at 287 kv; second, to determine the relation of diameter between stranded and segmental-type cable for the same corona-loss levels; and third, to determine the exact losses which were existing under the desert conditions upon 1.4-inch *HH* and other conductors and, if possible, the cause for the apparent increase in corona loss above that observed under atmospheric conditions at the Ryan Laboratory.

TEST LOCATION

IT WAS desirable that any test location be near one of the two switching stations, either Victorville or Silver Lake, so that connection might be made to a switch rack rather than tying into the transmission lines at a regular tower structure. Victorville was chosen for several basic reasons. There was available at Victorville, 183 transmission-line miles from the generator end, a voltage rise so that with slight overvoltages on the generators at Hoover it was possible to develop 365 kv for test purposes at Victorville. A water-column resistor-type wattmeter multiplier as used for the previous laboratory tests was installed.[2,5]

Water available from a well at Victorville had a specific resistance approaching 3,000 ohms per cubic centimeter which was suitable for use in such water resistors, while the water at Silver Lake carried a high chemical content and had very low resistance which would have required the use of distilled water. The fact that the unusual corona conditions had been observed only 14 miles to the east of Victorville, and the proximity of Victorville to Los Angeles, allowing for easy transportation of material and test crews, established this as the location for test. A section of right-of-way extended west from the switching station which eventually was to be utilized for the third circuit from Hoover Dam to Los Angeles was available upon which to erect the test line.

PHYSICAL ARRANGEMENT

VICTORVILLE switching station is the second sectionalizing station between Hoover power plant and Los Angeles and is located near a transcontinental highway. The station structure from which takeoff could most readily be accomplished terminated a portion of the bus tying directly to the section of transmission line extending between Victorville and Silver Lake Station to the east. A single span carried across the state highway to the start of the test line was the only construction necessary in addition to that required for the test specimens. Thus the test line electrically became a portion of the line between Victorville and Silver Lake so that under any fault conditions it would be relayed as a portion of that section of line. Under normal test conditions it was the Victorville end of such line with no switching at Victorville. To provide for emergency de-

Essentially full text of paper 50-141, "Desert Measurements of Corona Loss on Conductors for Operation Above 230 Kv," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

W. S. Peterson and **Bradley Cozzens** are with the Department of Water and Power, The City of Los Angeles, Calif., and **Joseph S. Carroll** is with Stanford University, Stanford, Calif.

energizing, switching was accomplished over the carrier-current relay circuit to Silver Lake. This switching, though provided, was never required during the test; normal switching was carried out by the regular supervisory control from Hoover power plant.

Four spans were provided for the erection of test conductors, the first two totaling 800 feet and the second two totaling 700 feet. These dimensions were selected because of irregularities in the terrain and in order to provide as nearly as possible similar ground clearance in all of the test spans and to accommodate the specimens available. The structures were of wood poles with latticed steel-channel crossarms and with guy supports to the tops of the poles to form an H-frame structure. Conductor spacing was $32^1/_2$ feet horizontal on a 65-foot crossarm identical with the Boulder lines. Ground wires, rather than being spaced 50 feet as on the Boulder line construction, were carried on the top of the poles at a separation of $32^1/_2$ feet but at elevations of 30 feet above the conductor as for the Boulder line. Suspension and dead-end structures, as they appeared during stringing operations, are shown in Figure 1. The slight variation in ground-wire spacing from that existing on the Hoover transmission circuits was shown to produce negligible change upon the voltage gradient at the conductor surface.

For the initial tests the two spans adjacent to the metering connection carried 800-foot specimens of 1.25-inch type-*HH* cable and the next two spans carried the 700-foot specimens of the 1.4-inch *ACSR* conductor. Jumper loops between the two specimens were provided for quick removal so that the combined losses from the two samples could be measured, followed promptly by the measurement of the losses from the specimen adjacent to the meters. The loss from the more remote specimen could then be determined by subtraction.

METERING

FOR METERING the losses at this location the fundamental circuit used was that described for measuring corona loss at the Ryan High Voltage Laboratory, Stanford University.[2,3]

Figure 1. Suspension and dead-end structures for supporting test spans

The scheme used a water resistor as a high-voltage multiplier for the voltage circuit of the standard low-power-factor wattmeter. The actual current into the conductor under test was carried through the current coils of this meter. Particular care was taken that all leads and the meters themselves were shielded to the point where losses were to be measured. Unlike the laboratory tests, this circuit used a fixed size of water resistor with resistance varying slightly with current and resultant temperature rather than maintaining constant current through the resistor as was the practice at the Ryan Laboratory. It was necessary at Victorville, therefore, to measure the resistance of the water entering the water column, the current actually flowing in the water column, and the water temperature in order to determine the heat being generated, the temperature rise, and the resultant total resistance of the column at the time each measurement was taken.

Figure 2. Arrangement of wattmeter multipliers and test connections

The general arrangement of equipment is shown in Figure 2. The down leads at the center of the jumper loop and connecting tubes over to the wattmeter assembly under the platform carry shielded leads from the wattmeters located on top of the water-resistor shield to the dead-end string, the first point where corona loss was measured. Observers during test runs were stationed on the platform above each wattmeter assembly reading through telescopes the wattmeters and milliammeters showing conductor current. Figure 3 shows a single water-column assembly. The shield at the top of the water column was approximately six feet in diameter with the outer edges composed of 2-inch iron pipe. Additional rings or loops were provided extending beyond the insulator supports. This large metal surface at the top, acting with the capacitance of the insulator stacks, provides a relatively uniform field along the water column hanging vertically from the center of the shield. The water resistors were made of capillary tubing approximately one-eighth inch

Figure 3. Water-resistor wattmeter multiplier for one phase. The water column hangs vertically from the center of the upper shield

in diameter. The water flow through this tubing was at the rate of from 15 to 20 gallons per minute, and the maximum current was somewhat below 50 milliamperes. For the voltages involved the energy dissipated in this column was at the rate of between 10 and 12 kw. Wattmeters were located in screen shielding cages on top of the shielding members. In addition to the wattmeter and charging-current readings, the current through the water resistors, approximate line voltage from coupling capacitors, resistance and temperature of water entering water column, generator voltage at Hoover received by telephone, wet- and dry-bulb temperatures for humidity, barometric pressure, and noise measurements were recorded with each reading of loss. The water-flow quantity and the normal resistance of the water in each of the water columns was measured between each test. The relations of the meters and measuring and shielding equipment is pictured in the circuit schematic diagram of Figure 4.

METERING ACCURACY

Wattmeters. The wattmeters used for these tests were the same meters previously used at the Ryan High Voltage Laboratory. Calibration was checked by several methods and by comparison with calibrated standards after they reached Los Angeles. Insignificant changes had occurred from the corrections previously applied so that values as actually read by scale divisions would correspond identically with those as determined under the Stanford conditions. Two sets of meters were necessary because of the two lengths of cable involved. Reading the meters through telescopes practically eliminated any error due to parallax. Reading was attempted to 0.1 of a division; estimates were probably within 0.1 of a division of the actual deflection. With some meter swing at the time of reading, the average readings probably were within 0.2 division of the actual value. This would correspond to 14 watts and 32 watts per phase respectively on the low- and high-range meters being used.

Voltage Measurements. Since variation in burden on coupling capacitors and saturation effects of iron components at the overvoltages involved made it questionable to rely upon this source for voltage measurement, voltage was determined at the test site by milliammeter readings of current and corresponding resistance of the main wattmeter resistors. Temperature of the water entering the base of each column was read with each two or three voltage readings. Coming from a large source there was little fluctuation in the temperature. Readings were taken to the nearest one-half degree. Water flow was measured before and after each group of readings, but since regulated pressure was maintained the flow also showed little variation. Since water has a finite temperature-resistance characteristic, the resistance of the water column varied materially with the voltage and consequent current and heating of the water. Current readings were made for each of the multipliers for each voltage applied. The error in these readings again was probably not over 0.2 of a milliampere, but since the normal readings was as low as 20 milliamperes, the error could thus be one per cent, or the equivalent of approximately 3 kv. Since three meters were read and compared, these errors probably averaged less than this amount.

The formula derived for the computation of the resistance of the water column from resistance, temperature, and current readings was as follows:

$$R=\frac{-Q(83.68-4.184T)\pm\sqrt{Q^2(83.68-4.184T)^2-335R_{20}(L/a)QI^2}}{I^2}$$

in which

R = the resistance of the column
R_{20} = the specific resistance at 20 degrees centigrade

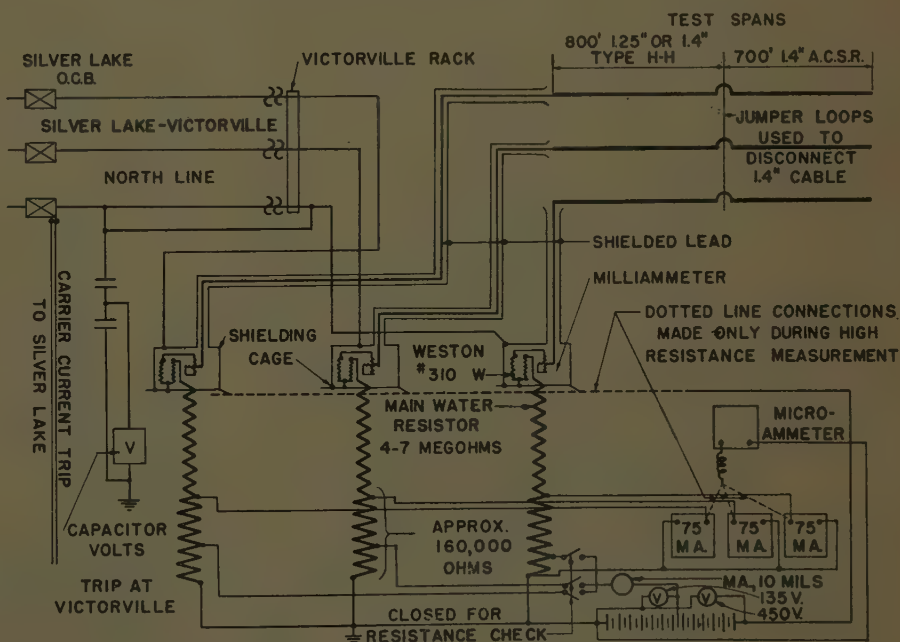


Figure 4. Schematic diagram of metering circuits showing relation to transmission line and test circuit

Q=the flow in cubic centimeters per second
T=water temperature in degrees centigrade
L and a=length and area of water column in centimeter units
I=the current through the water column in amperes

From studies of literature and measurements of the actual water being used, the formula for $R_{20}=[(20+T)/40]R_t$ was confirmed. By plotting the resistance values thus computed as a function of current, it was possible to establish a smooth curve relation, correct error readings, and be assured of a much higher accuracy than that for any single reading. It is believed that voltage determinations were within one per cent accuracy.

RESULTS OF TESTS

1.25-Inch Type-HH Cable. Tests on the 1.25-inch type-*HH* cable were conducted on four days extending over a period of nearly 12 weeks—September 26, October 17, October 24, and December 19. With the possible exception of December 19, the data for the several runs on individual days correlated so closely that a single curve could be plotted for each day and be representative of the entire group of data. Typical curves for these data are presented in Figure 5. It was necessary to make temperature corrections only where the cable temperature was greater than 102 degrees Fahrenheit by the first power relation of the air-density factor.

The first test conducted on September 26 was on the cable as received; before shipment its outside had been washed and rinsed. The loss at 287 kv was in excess of 6 kw per mile. After approximately four weeks of weathering, the test conducted on October 17 showed very little change in the loss, being only slightly lower in the lower region and a fraction higher in the region above 300 kv. At this time it was evident that the excess dye grease or lubricant carried on the inside of the cable was beginning to seep through the joints between the segments. Dust was collecting at these locations, and it was indicated that any reduction in loss resulting from weathering was being counteracted by these dust deposits and by small dust precipitation areas. These dust precipitation areas were generally elliptical in shape and occurred both on segmental and stranded-type cables. These were also observed on the Hoover line conductors, but after several years of weathering they are no longer found to exist.

The 1.25-inch cable was lowered, flushed internally with gasoline, and given the external gasoline, soap, and water wash identical with that normally given to conductors under laboratory tests.[3,5] Since the 1.4-inch stranded cable previously had received this treatment at the Ryan High Voltage Laboratory, it was given an external wash with clear water through a ring of high-pressure jets. Immediately following the washing treatment on October 24, the 1.25-inch cable, though indicating a slight reduction in loss in the lower loss range, had an increased loss of approximately 1 kw per mile at 287 kv, or a shift along the voltage axis of approximately 5 kv. In the upper range or high-loss range of the curve, the shift approached 10 kv; that is, the same loss occurred 10 kv lower than before.

Final test on this cable was conducted on December 19, two months later. At this time the loss had reduced somewhat; it was slightly less than 6 kw per mile at 287 kv for a cable temperature of 100 degrees Fahrenheit, but in

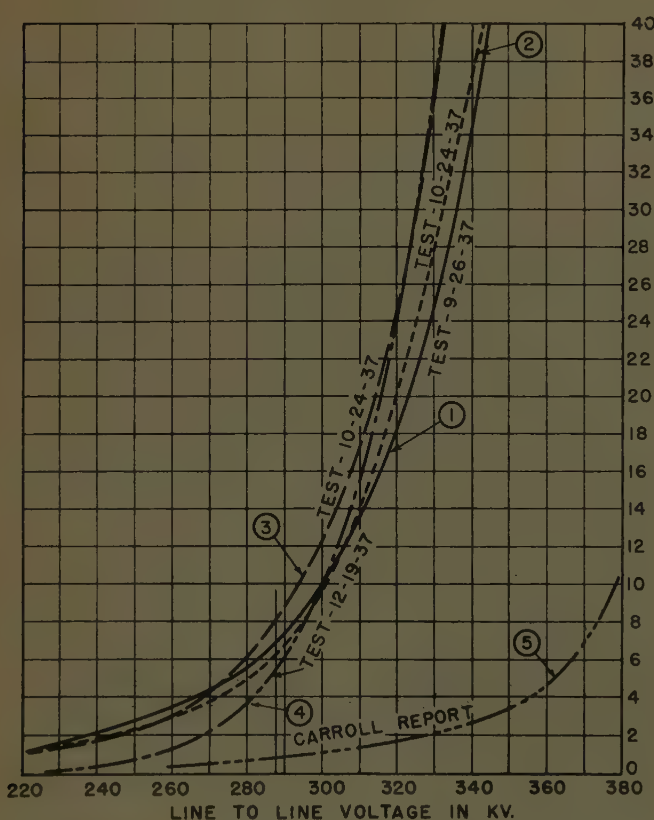


Figure 5. Curves of corona loss on 1.25-inch type-HH cable

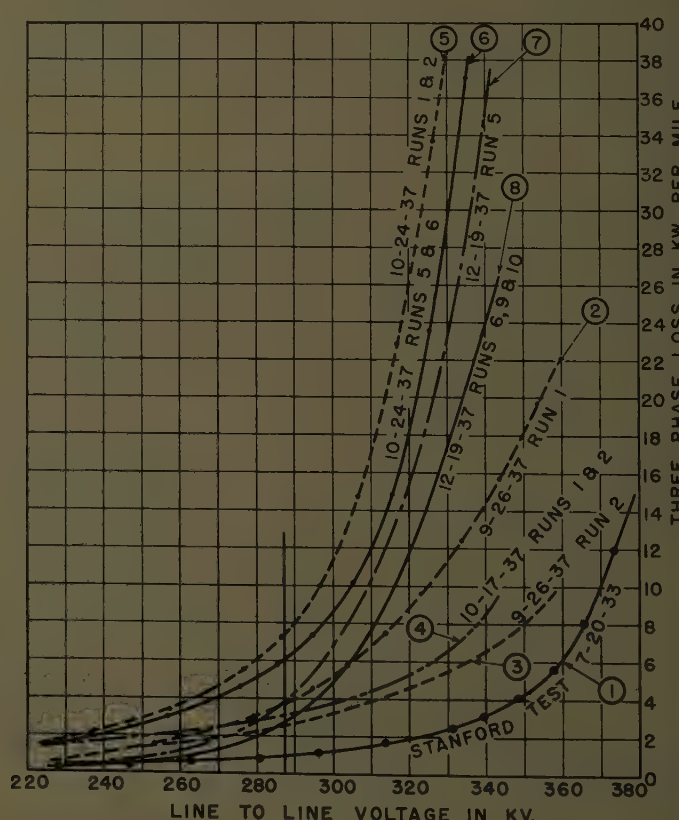


Figure 6. Curves of corona loss from 1.4-inch ACSR cable

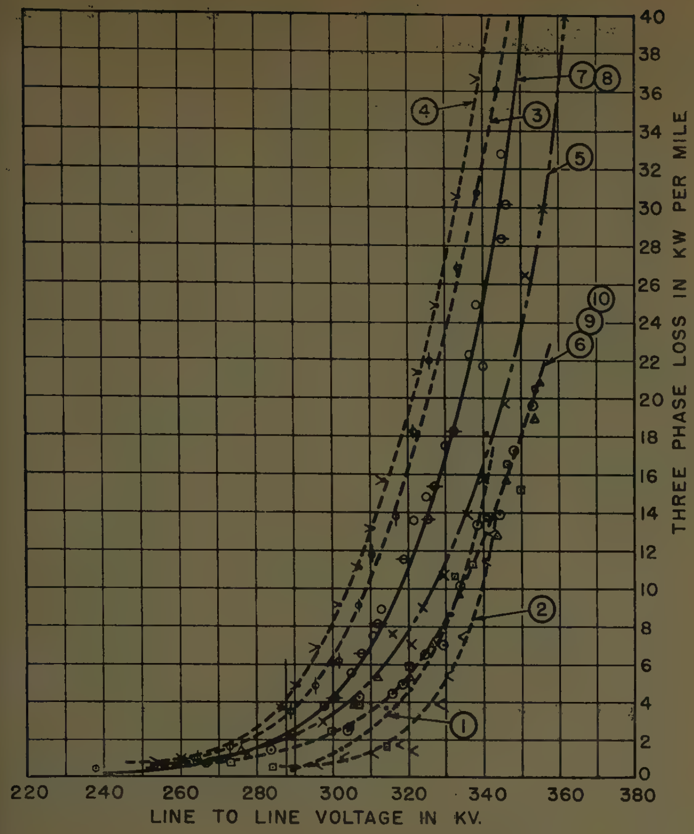


Figure 7. Curves of corona loss comparison of 1.25-inch HH and 1.4-inch ACSR cables

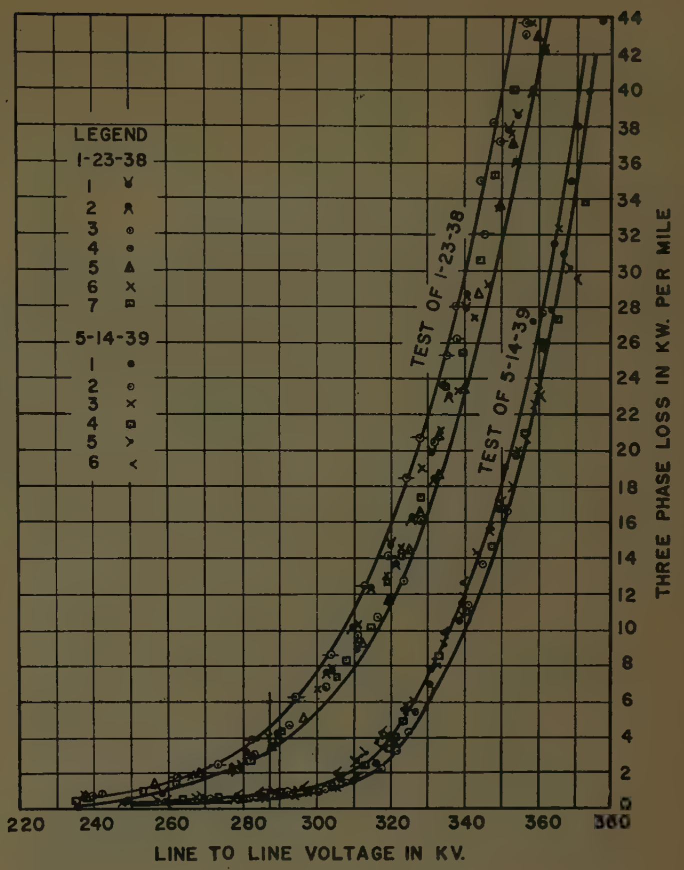


Figure 8. Curves of corona loss on 1.4-inch type-HH cable

carrying into the higher voltage range the loss was still above that determined under the initial erection conditions of the cable. For comparison a curve also is shown extrapolated from tests on 1.4-inch and 1.65-inch type-*HH* cable conducted at Stanford University which would indicate that for that location the corona loss on 1.25-inch type-*HH* cable at normal operating voltage of 287 kv would be less than 1 kw per mile. This change in loss is equivalent to a shift in voltage of over 50 kv in the lower loss range, while in the upper range of the curve a voltage shift of nearly 70 kv is necessary to produce the same loss. By comparing the results of these tests with those of tests at the Ryan High Voltage Laboratory some unknown factors are present in this area of the desert which cause corona to start at a voltage of 50 to 70 kv below that at which it is experienced on corresponding conductors at the Ryan Laboratory. In addition, contrary to the experience at the laboratory, the internal and exterior washing of the cable did not produce the normal reduction in loss previously experienced. The loss figures remained almost identical with those of the initial test; actually a slight increase was seen immediately following washing, and then with weathering the losses dropped below the losses experienced under initial test conditions.

1.4-inch ACSR Tests. Tests conducted on 1.4-inch *ACSR* are shown in Figure 6 and cover the identical dates mentioned for the *HH* conductor tests. The loss on the *ACSR* cable was determined by making a combined loss measurement on the two sections, including the 800 feet of 1.25-inch cable and the 700 feet of 1.4-inch *ACSR* conductor and then subtracting the loss computed for the former from the combined losses. Since temperature variations were usually very slight between consecutive runs and since the loss values as determined for the 1.25-inch cable showed little variation between runs on the same day, it was possible to use the loss values for the run immediately preceding or immediately following the combination run and thus be assured of a high degree of accuracy. It is of interest to note that the two runs on September 26 showed different results in the higher loss regions. The loss at normal operating voltage, 287 kv, for these two tests was between 2.5 and 4 kw per mile which corresponds to a voltage shift between the two tests of approximately 20 kv, while in the region approaching 10 kw per mile the curves showed a voltage separation of nearly 35 kv for the same loss. Tests conducted four weeks later on October 17 showed very little difference between consecutive runs, and the loss values were approximately midway between the two tests of September 26.

Following the test of October 17 the conductor was given an external rinse. Whether or not a surface condition had developed as a result of the treatment and storage at Stanford University which was removed as a result of this washing or whether dust accumulation in the desert during the short period of testing and after washing had modified the surface condition is not known. Immediately following this washing treatment on October 24 four test runs were taken. All of these runs fell within close limits, as indicated by the curves, but showed a material increase in the loss over the earlier tests. The loss at 287 kv was now in the vicinity

of 6 kw per mile, corresponding to a voltage shift from the earlier tests of approximately 50 kv and very near that of the 1.25-inch *HH* cable. The two groups of runs taken on this date were less than 10 kv apart in the upper range and approaching 5-kw separation in the range of 287 kv and below.

Tests conducted on December 19 again were consistent in showing approximately a 5-kv separation between various groups of runs throughout the major portion of the curve. This period of weathering of approximately two months reduced the loss in the lower range to values practically identical with those measured at the time the cable was erected but showing losses in the higher voltage range appreciably greater than those which were originally experienced.

The voltage shift for equal loss in the 287-kv region was from 10 to 20 kv (2 to 4 kw per mile) while in the 10-kw-per-

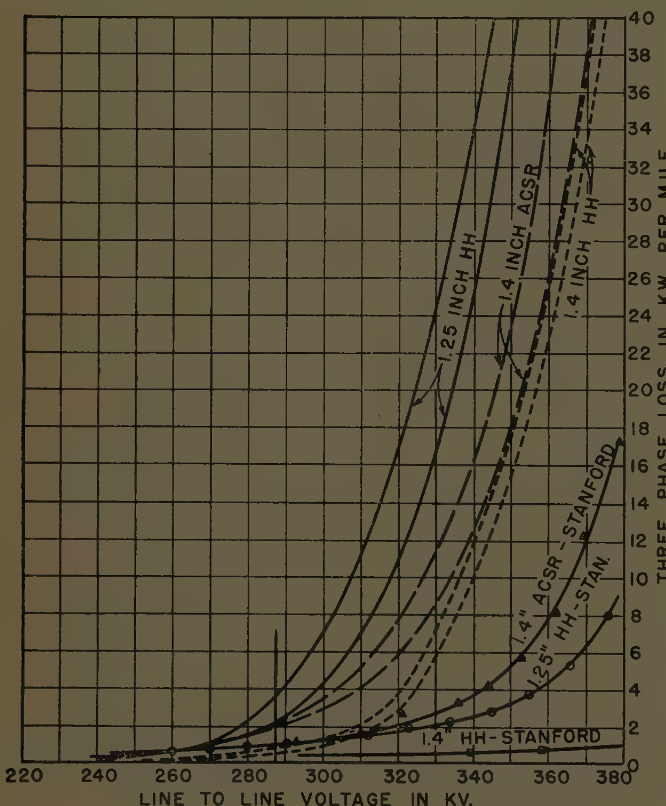


Figure 9. Summary of corona-loss data on 1.25- and 1.4-inch type-HH and 1.4-inch ACSR from Victorville and Stanford test

mile area the shift was between 40 and 60 kv, the curves rising abruptly for values above 287 kv. An additional curve from Stanford tests of July 20, 1933, on the identical cable is also plotted. This shows that for the stable condition of December 19, 1937, the identical cable would show the same corona loss under desert conditions at between 50 and 60 kv lower voltage than that required in the Stanford area.

The last test on these two conductors made on December 19, 1937, showed a moderate range of temperature from a starting temperature of 46 degrees Fahrenheit on the cable and 36 degrees air temperature through a maximum of 72 degrees on the cable and 61 degrees air temperature, and concluding with 63-degree cable temperature and 60.2-degree air temperature. A curve sheet, Figure 7, has been plotted covering these data correcting all to the approximate maximum value of temperature recorded, namely 70 degrees, on the cable. No correction was made for Tests 5 and 6 or 7 and 8 which are within two degrees of the correction temperature. Curves of Figure 7 are corrected using the first power of the air-density correction factor. Though data from Stanford tests indicated the use of the two-thirds power as a more accurate correction for conditions at that location, it was considered that the other factors which were being introduced on the desert would not justify this additional refinement.

1.4-inch Type-HH Cable. Immediately following the tests on the 1.25-inch type-*HH* cable and 1.4-inch *ACSR* cable, these cables were removed and replaced by three 800-foot sections of 1.4-inch type-*HH* cable as used on the Hoover circuits. This cable had been given an external wash with gasoline, soap, and water in order to speed the aging process yet keep it as nearly as possible like the cable as erected on the actual circuits. Since this cable had been closed with a soap solution, little difficulty was contemplated from internal greases exuding between the segments. Two groups of tests were performed—the first on January 23, 1938; the final group on May 14, 1939, after 16 months of weathering. Figure 8 covers the data which were secured from these two tests.

Curves have been drawn indicating the approximate extreme limits of these data for each test, and plotted points are included showing the manner and variation between consecutive runs. All data have been corrected to 70 degrees Fahrenheit. The 16 months of weathering reduced the loss in the operating range from 4 kw per mile to less than 1 kw per mile. This was equivalent to a horizontal shifting of the curves of somewhat in excess of 30 kv.

Figure 9 summarizes the data accumulated at Victorville and includes typical curves from previous measurements at Stanford University corrected to Victorville conditions for the 1.4-inch type-*HH* and *ACSR* conductors and 1.25-inch data as extrapolated. The Victorville data are plotted as areas or limits within which losses may be expected after normal weathering conditions. The advantage of the segmental-type conductor, both for desert operation as well as for conditions existing near the Ryan High Voltage Laboratory, is clearly indicated. The differential, however, is not as great under desert conditions as was previously contemplated.

REFERENCES

1. Symposium on Operation of the Boulder Dam Transmission Line—Corona Experience on Transmission Line, **Bradley Cozzens, Wm. S. Peterson.** *Electrical Engineering* (AIEE *Transactions*), volume 58, April 1939, pages 137–40.

2. Corona Loss Measurements on a 220-Kv 60-Cycle 3-Phase Experimental Line, **J. S. Carroll, L. H. Brown, D. P. Dinapoli.** AIEE *Transactions*, volume 50, March 1931, pages 36–43.

3. Corona Loss Measurements for the Design of Transmission Lines to Operate at Voltages Between 220 Kv and 330 Kv, **J. S. Carroll, Bradley Cozzens.** AIEE *Transactions*, volume 52, March 1933, pages 55–62.

4. Discussion by **Wm. S. Peterson** of Reference 3. AIEE *Transactions*, volume 52, March 1933, pages 62–3.

5. Corona Loss From Conductors of 1.48-Inch Diameter, **Joseph S. Carroll, Bradley Cozzens, Theo. M. Blakeslee.** AIEE *Transactions*, volume 53, 1934, pages 1727–33.

Performance of Electric Locomotives

A. H. CANDEE

Comparison of the power and tractive force characteristics of the reciprocating steam locomotive, the trolley locomotive, and the self-propelled electric locomotive indicates that electric traction gives superior performance capabilities over mechanically driven locomotives of the reciprocating steam type.

UNTIL the general adoption of the diesel-electric locomotive within the past 15 years almost all railroad men considered that an electric locomotive was one whose power is generated in a stationary power plant and transmitted to the locomotive by means of a trolley wire or third rail. This limited conception has changed with the growing realization that the most important operating characteristics of diesel-electric locomotives are due to the electrical transmission of power from the prime mover to the wheels, and that nearly all of these same characteristics are to be found in any electric locomotive, such as the trolley- or third-rail-electric, the steam-turbine-electric, the gas-turbine-electric, or the storage-battery-electric locomotive.

TRACTIVE FORCE AND POWER RELATIONS

THE SPEED-TRACTIVE-FORCE and speed-power characteristics of various types of motive power are, in general, vaguely understood by most operating men. While a practical evaluation of the relationship of these has been acquired for steam power, the application of thousands of diesel-electric locomotives within recent years has confused the situation and has resulted in many mistakes in loading and dispatching of the latter type, resulting in costly electrical repair expenses. The most economical operation will result when the characteristics of this modern power are understood by the operating personnel.

The tractive force required to move a given weight of train over a railroad is dependent upon the physical characteristics of the railroad itself rather than upon the motive power. This is modified to some extent by the quantity of power applied, since this affects speed and hence changes those resistance factors which are the result of speed. The tractive force required to move a train of given weight and consist over any particular section of a railroad must be sufficient to overcome the resistance values imposed by grades, curvature, rigidity of rails and roadbed, temperature, direction of wind, speed of train, and so forth. The speed at which the train moves, however, is dependent upon the power available for this purpose.

The maximum tractive force which may be developed is a function of the weight on drivers or the physical or electrical limits of the power transmission system. The weight on drivers is important because this, when multiplied by the factor of adhesion between the driving wheels and rails, imposes an ultimate limit of tractive force. While this factor remains fairly constant whether the wheels are stationary or are rolling along the rails, the effect of locomotive movement is to create inequalities in wheel loadings, this variance tending to rise as locomotive speed increases. The result is that the effective adhesion between a group of wheels and the rails decreases at higher speed, the general values approximating those shown by Figure 1 which is an average of many railroad tests for dry rails. From this it is obvious that it is not always possible to apply the full available power of a locomotive to the wheels, because to do so would cause the wheels to slip. This is particularly applicable to trolley-electric locomotives, where high power application is possible, and also to some of the modern designs of steam locomotives having a relatively limited number of driving axles.

Until recently, the steam locomotive has been the basic type of locomotive upon which American transportation has depended. It appears, then, that explanation of the fundamental characteristics of electric motive power may best be made by comparing them with like characteristics of the steam locomotive.

STEAM LOCOMOTIVE CHARACTERISTICS

THE FAMILIAR steam locomotive is of the reciprocating type, generally with two cylinders (except for extremely heavy hauls or the case of some modern locomotives of high power), and with direct mechanical drive through connecting and side rods. The capabilities of such locomotives are seldom expressed in concrete terms, since there is little of a tangible nature by which their performance in railway service can be defined. Railroad men, familiar with this type of power, find it sufficient to refer to them by such terms as an "8-wheel switcher," a "Consolidation," a "Mike," a "4-8-4," a "Mallet," or similar known and descriptive terms. Horsepower cannot be definitely tabulated because of fluctuations caused by variations in firing rates, quality of coal, changing evaporative conditions, in-

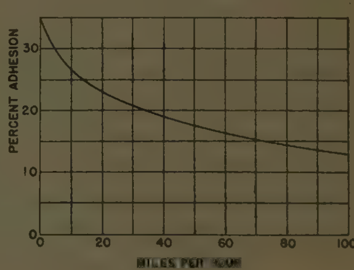


Figure 1. Effective factors of adhesion between wheels and rails (dry rails, approximately)

Essentially full text of paper **50-180**, "Power, Pull, and Performance of Electric Locomotives," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Not scheduled for publication in AIEE *Transactions*.

A. H. Candee is with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

accurate adjustment of cutoff, and similar factors. The only semidefinitive figure is that of starting tractive force, which may be calculated from boiler pressure and the physical dimensions of the cylinders and wheels. With the starting tractive force and general type of locomotive known, however, transportation men have been able by long experience to judge the service capacity of such a locomotive very closely. This follows from the fact that the horsepower capabilities built into the boiler usually bear an operating relation to the starting tractive force. The assumption that this same factor applies to electric locomotives, particularly to diesel-electric locomotives, has led to some embarrassing situations.

The boiler of a steam locomotive has a relatively constant evaporative rate, and any steam locomotive which can utilize this steam efficiently at all speeds should develop

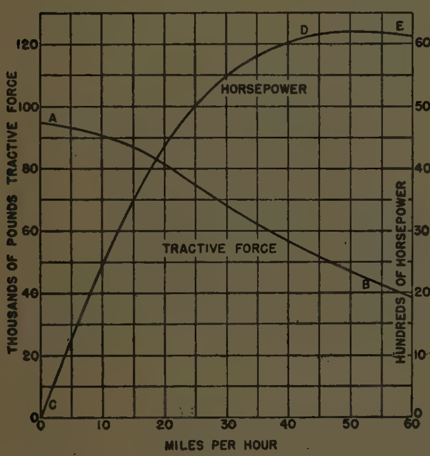


Figure 2. Characteristic curve of a 2-10-4 steam freight locomotive

essentially constant horsepower. The reciprocating locomotive with direct drive, however, does not use steam efficiently except over a very narrow speed range. The resulting characteristic, then, is that of horsepower rising to a peak and then falling off as the limit in locomotive speed is approached. This is illustrated by Figure 2, which is the characteristic curve of a 2-10-4 steam freight locomotive having a total weight on the ten driving wheels (five driving axles) of approximately 380,000 pounds. This type is normally considered one of the more powerful of those driven by a single pair of cylinders. While the starting tractive force is 95,000 pounds, which is 25 per cent of the total weight on drivers, this force varies considerably during each wheel revolution, and the peak force when developing an average of 95,000 pounds is approximately 114,000 pounds, or 30 per cent of the weight on drivers, which approaches the adhesive limit between the wheels and the rails. Since it is this peak force which initiates the slipping of wheels, the comparisons which follow will be based upon equal adhesions, which are 25 per cent average adhesive limit (actually 30 per cent peak) for steam and 30 per cent (constant force) for electric locomotives. Curve *AB* shows the speed–tractive-force characteristic, and curve *CDE* defines the horsepower output at different locomotive speeds. The maximum starting tractive force of 95,000 pounds was limited by the total weight on drivers. All portions of these curves are within the adhesive limits as defined by Figure 1.

TROLLEY-ELECTRIC LOCOMOTIVE CHARACTERISTICS

Characteristics of trolley-electric locomotives vary widely according to the type. In some of these, power is transmitted from the trolley directly to the traction motors. In other types, the power undergoes conversion before reaching the motors. The motor-generator locomotive and the proposed rectifier locomotive are of the latter type. In addition, there are special types, such as split-phase locomotives, which need not enter into this discussion. The motor-generator type was and the rectifier locomotive can be built with constant horsepower with characteristics similar to those of the diesel-electric locomotive. The form which is of comparative interest here is that wherein trolley power is transmitted directly to the traction motors.

One of the prime advantages of trolley-electric locomotives in heavy and congested services is the availability of ample power for rapid accelerations and fast schedules. High power input can be sustained to much higher speeds than with other forms of motive power and (with suitable traction motor size and gearing) high power is available over the entire running range. Figure 3 shows the tractive force and horsepower characteristics. With the wheels independently driven there is no theoretical restriction to the number of axles which may be driven, so that practically unlimited starting tractive force and power can be obtained if desired. However, it has been the practice in the past to keep the number of driving axles to a minimum, and Figure 3 represents a 2-unit locomotive with a total of six driving axles.

Curve *ABCD* is the speed–tractive-force curve, restricted by adhesion (Figure 1) between *B* and *C*. Curve *EFGH* is the speed–horsepower curve, again restricted between *F* and *G*. In this case, the tractive force at start is limited by adhesion, but in some high-speed trolley-electric locomotives the limit is imposed by the commutating characteristics of the motors rather than by adhesion.

DIESEL-ELECTRIC LOCOMOTIVE CHARACTERISTICS

The widespread use of diesel-electric locomotives has focused attention on the constant horsepower type of locomotive. In this type, the diesel engine drives an electric generator which is usually regulated to take constant horsepower from the engine for traction purposes when the engine is operating at its full speed. Since individual motors are used for driving axles there is no theoretical limit to the number of driven axles nor to the starting tractive force which can be obtained. Practically, however, diesel-electric locomotives with more than 400 diesel-engine horsepower per axle are either used for high-speed services (such as passenger duty) or are likely to be considered slippery.

The speed–tractive-force curve of a typical 4-unit 6,000-horsepower diesel-electric locomotive with 16 driving axles is shown by Curve *ABC* of Figure 4. The section from *A* to *B* reflects the limit imposed by adhesion between wheels and rails, while that from *B* to *C* is essentially hyperbolic (constant power) as modified by transmission losses. The horsepower curve resulting from the speed–tractive-force curve *ABC* is shown by curve *DEF*, which totals 6,000 horsepower minus the electrical losses.

COMPARISON OF CHARACTERISTICS

It is generally recognized that more power may be built into a single-unit trolley-electric locomotive than any other type, and that steam is next. The diesel-electric locomotive is far below either of these, but such apparent weakness has actually proved to be one of the most important advantages of this type of power, because small, independent units (each with four motors) can be built. The correct horsepower is obtained by operating the required number of units in multiple. Locomotives of high horsepower, then, invariably have plenty of driven axles for smooth starting and for heavy pulls.

In comparing locomotives, maximum horsepower capacity of each must be given due weight, although the tractive force developed at different operating speeds (or horsepower at particular speeds, since horsepower = pounds of tractive force × miles per hour ÷ 375) is of considerable importance. Nearly all electric locomotives have tractive force values greater than steam throughout the lower speed range, and thus have a distinct advantage over mechanical drive units. Figure 5 shows the speed–tractive-force and Figure 6 the speed–horsepower characteristics of the steam, trolley-electric, and diesel-electric locomotives selected for comparison (actual locomotives used for a heavy freight service). General dimensions of these are given in Table I. There is

Table I. Comparison of Three Locomotive Types

Locomotive Type	Steam	Trolley-Electric	Diesel-Electric
Number of driven axles	5	6	16
Weight per driving axle, pounds	76,000	70,000	57,500
Total weight on drivers, pounds	380,000	420,000	920,000
Maximum speed, miles per hour	70	70	65
Maximum tractive force, pounds	95,000	126,000	276,000
Maximum developed horsepower	6,200	9,600	5,100
Continuous rating, pounds	95,000	60,000*	210,000*
Adhesive factor at rating	0.25†	0.143	0.228

* Electric equipment rating.

† Average.

a wide difference in the tractive force values of the trolley and diesel-electric locomotives, but these particular locomotives were chosen to exaggerate this difference in order to show the improvement effected by motoring more axles. A 6,000-horsepower diesel-electric locomotive was picked because its power closely approximated that of steam. In an actual application, superior starting ability might allow the use of a 4,500-horsepower diesel-electric locomotive where a 2-10-4 steam unit is replaced. It should be noted that many trolley-electric locomotives are in service with more driven axles and greater starting force than shown in the table.

ANALYSIS OF CURVES

The trolley-electric and the diesel-electric locomotive have each been applied as a competitor of reciprocating steam power. The advantages of the trolley-electric type (aside from economic aspects) are the ability to start heavier trains, to accelerate at high rates, and to sustain high speeds, thus increasing the capacity of a railroad. The diesel-electric locomotive, as against steam, has the ability to start heavier trains and to move them over the most severe grade conditions of the railroad. Thus, the two types of electric locomotives may have distinctly different operating characteristics, yet each fulfill its particular mission.

The trolley-electric locomotive which is being used for comparisons represents an era of thought which is apparently passing. The ideas in effect at the time that these were built followed steam practice to some extent; the number of drivers of each unit were kept to a minimum and mounted in a single wheelbase to reduce cost. Weight per axle was kept high to procure high adhesive weight. Grades are not severe where these are used, so that extremely high starting values of tractive force are of less importance than high developed power at the elevated speeds. As against this, the development of the diesel-electric locomotive has been on the basis of standard units in quantity production, which introduced the necessity of applying such units to a wide variety of grade and service conditions. Thus, for general application, units must be built with maximum tractive force capabilities yet with a limit to the weight per axle. By building relatively small units operated in multiple and by using swivel trucks, both objectives have been accomplished. This construction is now being adopted for some trolley-electric locomotives.

In the series type of traction motor used for locomotive propulsion, when operating at a constant voltage, the current draft and the horsepower fall as the locomotive speed rises and vice versa. The general shape of this horsepower characteristic is shown by the curve portion *GH* of Figure 3. This means that to have sufficient horsepower to give satisfactory performance at high speed, the possible power draft at start is far beyond that which can be utilized. For this reason, characteristics more closely approaching constant horsepower are now looked upon with considerable favor. The shape of the curves for such a locomotive should be somewhat higher than those of the diesel-electric locomotive, approaching the limits of adhesion over the speed range as closely as is found expedient.

The reciprocating steam locomotive will probably never approach the capabilities of any electric locomotive. Since connecting-rod drive restricts the driving wheels to a rigid wheelbase, and because there are practical limits to the length of rigid wheelbases (if the railroad has any curves), it follows that the number of driving wheels and, therefore, the maximum starting tractive force, will always be lower

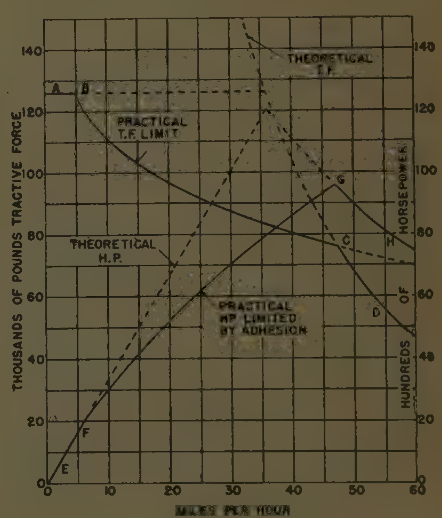


Figure 3. Characteristic curve of a double-unit trolley-electric freight locomotive

than for electrically driven units. The obvious future for steam power, of course, lies in the successful development of the steam-turbine-electric locomotive.

PULL AND POWER FOR VARIOUS SERVICES

THE CURVES shown by Figures 2 to 6 are typical of each of three types of locomotives. The reciprocating steam locomotive has relatively low starting tractive force and cannot utilize its power until reaching high speed. The electric types may be built with several different characteristics, the most useful for general railroad applications being of the approximate shapes shown by the diesel-electric curves.

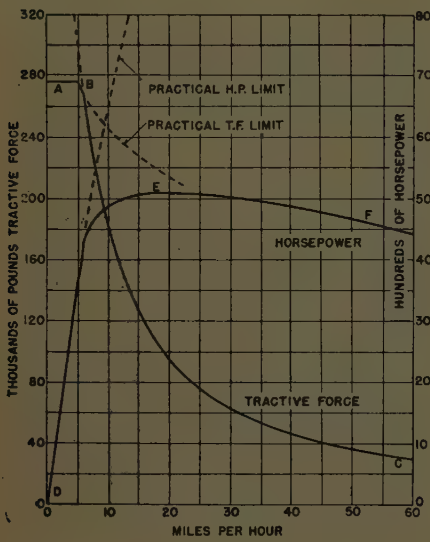


Figure 4. Characteristic curve of a 4-unit diesel-electric freight locomotive

In yard switching work, high starting tractive forces and the development of full horsepower at low locomotive speeds are of prime importance. This permits the unit to couple to a heavy train and switch out the individual cars most expeditiously. Since this is slow-speed work, high horsepower is not necessary, and the low-powered electric locomotive (the diesel-electric) has far surpassed any other type for this purpose. Because of the number of yard tracks, self-propelled rather than trolley-electric locomotives are preferable. In the operation of gravity classification yards, tractive force demands are unusually high but again the horsepower requirements are low. The best motive power for this purpose has been found to be diesel-electric locomotives of low or medium power provided with more than the usual number of motored axles.

Transfer service is the handling of heavy cuts of cars, usually from one point to another within a switching district. The motive power for such services must have high starting and sustained tractive force, preferably with greater power than for switchers but not as great as that necessary for road service. The high tractive force capabilities of electric locomotives are of considerable value in this type of service.

Road services impose a wide variety of operating conditions upon locomotives. In freight service there is generally one particular grade that limits the tonnage handled over a division, and the peak power of the locomotive is relatively unimportant. Those types of electric locomotives which have a large number of driven axles have raised the tonnage limits far beyond those possible with steam power, and even though the steam locomotives had greater potential power at high speeds, heavy grade operations seldom permitted their effective use. In passenger work this situation is somewhat different. While ample starting forces are most desirable for smooth starting and handling of trains, available horsepower over the higher ranges of speed is also important. In this respect the trolley-electric locomotive, if correctly designed, surpasses other types, while steam usually develops more power at elevated speed than a diesel-electric locomotive which replaces it and which maintains schedules more easily. The advantages of this excess steam-locomotive power are offset by higher power input at medium speeds and the better speed recovery of the electric type when a slowdown or a stop is made.

HANDLING HEAVY TRAINS

COMMERCIAL CONSIDERATIONS introduce one factor into the application of electric locomotives which is generally new and somewhat confusing to the former operators of steam power. This is the time limit on the exertion of high tractive force imposed by the heating of electric equipment. Another restriction, peculiar to all electric drive systems using commutator motors, is that the prolonged application of power with the locomotive at standstill cannot be permitted because of probable damage to commutators.

Figure 4 shows that the diesel-electric locomotive used for comparisons can exert a maximum tractive force of 276,000 pounds, as limited by slipping of drivers. The electrical rating for continuous operation, however, is but 210,000 pounds, this figure being fixed by the heat losses in the electric machines, the ability of the ventilating system to remove this heat, and the maximum temperature allowable for insulating materials and solders. When tractive-force values greater than 210,000 pounds are exerted for starting or for negotiating heavy grades, excess heat is generated and the temperature of the machines tends to increase. Obviously, if this overload is applied with machines cool, it may take an appreciable time to reach dangerous temperatures, and it is this time lag which is frequently relied upon to get trains over bad grades that are short enough to be negotiated within the time-temperature limits of the electric apparatus which is being used.

As indicated, the application of electric traction apparatus, which has tractive force limitations below the maximum which may be exerted, is based upon commercial considerations. It is possible to provide equipment whose continuous electrical rating exceeds the maximum load which can be imposed upon it at the slipping point of the wheels. However, few railroad services can utilize this high capacity to its fullest extent, and where electric locomotives are built in standard sizes for miscellaneous applications (as are diesel-electric locomotives), it is not logical to burden every user with the high cost of such extra-capacity equipment. Slightly reduced capacity is provided, therefore, and the limitations imposed by this are accepted in the interest of reduced capital investment. Actually, with new technological developments, continuous electrical

ratings are being raised and are approaching the point where risks of overheating are negligible.

In establishing tonnage ratings for electrically driven locomotives, factors other than direct-rating figures must be considered. Dragging brakes, high winds, and similar conditions may increase train resistance and slow a train beyond the time limits of the short-time ratings. Likewise, loss of one power plant of multiplant locomotives not only reduces the total power and thus reduces train speed, but also reduces the number of traction motors receiving power, thus increasing the load of the other motors. There is a psychological urge on the part of enginemen to keep moving in spite of such failures. The results of overheating from such operations do not always appear at once, but failure may occur a week or a month or two months later, and the origination of the cause of failure cannot be traced. Repair expense and costly road delays will be reduced if the railroads do not load electrically driven locomotives to their utmost limit.

As mentioned, electric traction motors of the commutator type must not remain stationary with current flowing because of the danger of heating and burning of the commutator bars directly under the brushes. This means that the practice used when steam locomotives serve as helpers must be avoided. The normal procedure is to couple the steam locomotive back of the train and to open the throttle, so that when the principal locomotive starts the helper automatically exerts its share of the accelerating force. Because this must not be done with electric motive power, its use normally involves signaling between the head and rear ends of a train before power is applied.

The operation of electric helpers sometimes involves the matching of locomotive characteristics or else the limitation of tonnages. When two or more locomotives are used to move a train, both, of course, operate at the same speed. Assume that the principal locomotive has a continuous electrical rating which falls at a speed of 14 miles per hour, while the helper's falls at approximately 18 miles per hour. If the grade and train weight are such as to cause the train to operate at 14 miles per hour (which may appear satisfactory, since it is within the rating of the principal locomotive) then the helper locomotive will be considerably overloaded on this grade. For this reason, when principal and helper locomotives have different characteristics, it is good practice to limit train weights to those which will allow the maintenance of speeds well above the higher of the locomotive rated speeds for long, heavy pulls. This is especially important when an electric locomotive helps a steam locomotive, since no damage can be done to the steam locomotive no matter how low the train speed falls, or even if it stalls.

ELECTRIC TRACTION MOTORS

The most widely used type of traction motor for electric locomotives is the series-connected commutator-type motor (armature and field windings connected in series, with the same current flowing through both). These are constructed for either a-c or d-c power systems, but the a-c motor is the more expensive to build and to maintain. Other types, such as wound-rotor induction motors, doubly fed a-c motors, shunt motors, compound motors, and so forth, have been used to a limited extent, but the series-type commutator motor has natural characteristics unsurpassed by any other for rail traction purposes. The real features of this type of motor are that it adjusts itself instantly to changes in operating conditions, it requires the minimum flow of current (and, therefore, motor heating) to produce high tractive force, and it has a much steeper curve than other types of motors. As an added attraction, the control of power flow to such motors for the regulation of locomotive movements is relatively simple.

DYNAMIC BRAKING

Dynamic braking is any system of electric braking in which the traction motors, when used as generators, convert the kinetic energy of the train into electric energy, and in so doing, exert a retarding force on the train. This is one of the extra operating conveniences which is practical only with railroad electrification. Two forms of this type of braking are regenerative and resistance braking, the former returning recovered energy to the power system and the latter dissipating this energy to the surrounding air by means of resistors.

Regenerative braking has long been used in connection with trolley-electric locomotives, principally where grades are long and severe and where traffic can be dispatched to make the most effective use of the recovered power. Resistance braking has been used for approximately 50 years on streetcars but has just come to the attention of many railroad men since its application to diesel-electric locomotives. For the latter type, where energy cannot be stored or returned to a power network, dynamic braking can be effected best by dissipating the electric energy to the surrounding air.

Dynamic braking has been applied to a wide variety of grade and service conditions. The simplicity and utility of resistance braking recommends itself even for trolley-electric locomotives, because the amount of power generally recovered by regenerative braking is seldom sufficient to justify the complications involved in arranging for this type of electric braking.

It is well known that full train retardation by dynamic braking is available only over a limited range of train speeds, the restrictions being imposed by traction-motor

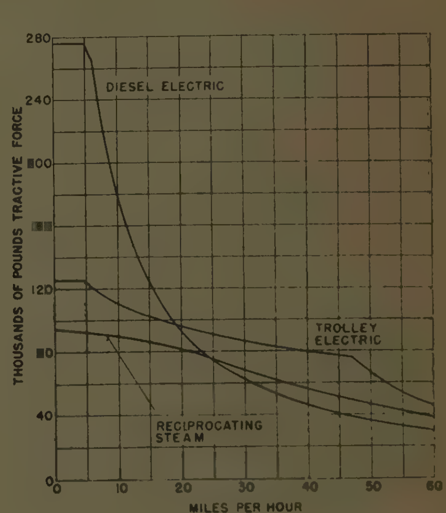


Figure 5. Speed–tractive-force characteristics of three types of freight locomotives

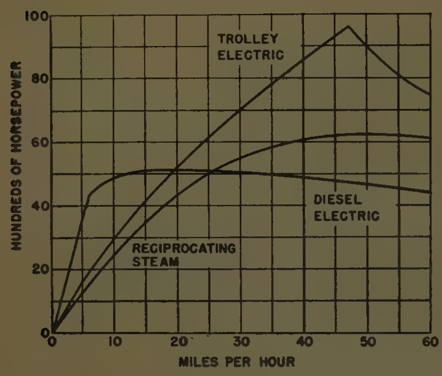


Figure 6. Speed–horsepower characteristics of three types of freight locomotives

design limits. However, full braking to maximum adhesive limits over the complete range of operating speeds is not a requisite for satisfactory handling of trains down moderate grades. Where heavy grades are encountered, braking forces up to the slipping point of the wheels can be obtained over a range of train speeds which are normally satisfactory and safe for those grades. The attractive features of dynamic braking are that it is smooth, easily regulated, and reduces the use, wear, and heating of mechanical braking parts, leaving these in reserve for emergency use or to bring a train to an actual stop.

APPLICATION OF ELECTRIC LOCOMOTIVES

POWER AND PULL are two indispensible components of a locomotive application. Because electric propulsion permits the development of high tractive-force values with reduced tendencies for wheels to slip, many operators catalogue electric locomotives by this characteristic alone, and a few expensive mistakes have resulted therefrom. A 6-motor 1,500-horsepower diesel-electric locomotive may have starting and continuous rating tractive-force values far exceeding those of a steam freight locomotive, but it is a serious misconception to expect that such a unit will move trains over the road as expeditiously as will the steam locomotive.

There are many applications where maximum tractive force capability is of prime importance and where developed horsepower may be almost neglected. Such is the case for yard-switching operations, gravity classification yard work, and similar services. On the other hand, high tractive force is of but medium importance and power concentration is of greatest necessity on a busy piece of railroad where train movements must be fast and sure to avoid serious congestion. It has been said that the large trolley electrifications of our eastern seaboard would not have been attempted had the diesel-electric locomotive been developed at that time. While close comparative figures for this have not been worked out, it does not seem probable that enough diesel-electric power units can be assembled as single locomotives and maintained to keep this fast and heavy traffic moving with the regularity and margin of security now existing. This is because such services require power rather than tractive force, and trolley-electric locomotives can be built with much greater power per unit than self-propelled locomotives. As a matter of fact, trolley electrification, which results in increased train speeds, may be the best way of securing additional track capacity as traffic increases over some of our restricted railroads, such as those through mountainous regions where double tracking or the construction of additional passing tracks is very expensive.

Any value of tractive force may be secured for an electric locomotive by operating a number of power units in multiple. The use of a single locomotive with the full tractive force necessary to move a train, however, is not always the answer to a railroad's operating problem, because severity of curvatures and strength of drawbars frequently make it necessary to divide the power into two or three parts and to distribute it at the front, rear, and (sometimes) at an intermediate point of the train. When such conditions exist, relief may be afforded by building more power rather than tractive force into each locomotive and by operating lighter trains at increased speeds and frequency.

There is considerable controversy as to a safe factor of adhesion upon which motive power may be applied with the assurance that tonnage ratings based thereupon may be handled under all weather conditions. Engineers experienced in the application of trolley-electric locomotives almost invariably limit their adhesive factors to 17 per cent or less, while those accustomed to diesel-electric locomotives often feel safe in loading locomotives to adhesive factors in excess of 20 per cent. Figure 1 has been drawn to show average effective adhesive factors which may be expected with dry rails. Naturally, rails are more slippery when covered with water, ice, snow, or frost, but the general shape of the curve is similar to that shown except at lower values. Since the effective factors of adhesion decrease as the locomotive speed rises, and because tractive force values of trolley-electric locomotives may be sustained to higher speeds than with the standard diesel-electric units, it follows that for any comparable tractive force the trolley-electric locomotive adhesion falls farther out and lower on the curve than for the diesel-electric locomotive.

The power input of different types of locomotives is but one of the elements determining the maximum assured adhesive factors which may be used for the determination of all-weather train tonnages. Another very important consideration is the track curvature existing in the area where maximum pulls must be developed, because curves in themselves are conducive to wheel slippage. Still other limitations are imposed by the transfer of weight between the various driven axles when pulling, and the effectiveness of the weight equalization systems of locomotive running gears.

IMPROVED PERFORMANCE THROUGH ELECTRIC DRIVE

THE IMPROVED operating features of electric drive are generally recognized and portend an increasing use of electric equipment for supplying power to locomotive driving wheels. All locomotives using this type of transmission have important basic advantages over other types of motive power, with the choice between the different kinds of electric locomotives dependent upon the amount of power required, the over-all operating costs, the reliability of the prime mover or power supply, and the investment involved. There is little doubt that the tremendous savings which have accrued to the railroads through the use of diesel-electric motive power have been made possible by the superior train-handling abilities endowed them by electric drive.

108 Are Missing

E. C. HUNT

A review of the data concerning death-causing accidents happening during the past 18 years at one large utility company is analyzed to obtain ideas and methods to be followed to obtain better safety in the future.

Of all the ramifications of engineering, the limitations of the human are the least understood and considered. In direct contrast research has established basic specifications and limitations for materials used by man. Engineering has made standards using factors for security and tolerance. The term "working load" is often used relative to material things, but expectations for human behavior are not evaluated.

Sights for the future may be reset with precision with reference to past factual data, opinions and conclusions re-valuated for the purpose of establishing better understanding for ways and means to minimize recurrences of dangerous exposures or acts.

This article will not dwell on the frequency or the severity factors but will endeavor to convey an analysis of what has transpired over a number of years in one large utility company.

Figure 1 indicates briefly the entire story. The first four classifications in importance are comparable to the ratios presented by the Edison Electric Institute for the industry during the past several years. The rim of this wheel indicates a reclassification based upon the facts presented here. Contributory neglect and human failure are seen to be the cause of most accidents.

ELECTRIC SHOCK OR BURNS

Line Work. The most important problem in the industry is electric shock or the result—burn. Nearly 41 per cent of the cases occur on line work while men are working on poles and structures, and nearly 24 per cent occur to line crews on the ground. These accidents happen in spite of a high standard of working conditions in overhead line construction; in most companies clearances and working conditions on the pole have been and are well planned and followed. Improvements are being made in both design and installation. In none of the 24 cases happening on poles and structures has any fatality occurred because of congested or very poor working conditions. There was but one fatality due to an infraction of the Rules and Regulations set up by the Public Utilities Commission for overhead line construction. On the other hand, there have been several men injured, two fatally, when minor infractions occurred. Of the 24 cases there were six in which the employee lost his life by making contact with an energized 4-kv conductor between the elbow and the end of the gauntlet of the rubber glove during the period when the 14-inch gauntlet glove was used, and there were three cases where men were in the primary area without gloves, standing idly by, waiting, smoking, and so forth, when each absent-mindedly contacted an energized 4-kv part. It is well to review this for so many young men who are now in the business. Much of the work they have accomplished has been done on new line extensions, secondaries, and so forth, while de-energized, where they may have adopted some poor working habits. The new man must be made aware of the tricks that the human mind will play on the individual to cause him absent-mindedly to do the unthinking thing and come in contact with an energized line.

Standards have to be adopted and strictly adhered to. Human nature makes men grow complacent about their surroundings and prone to take chances. To keep out of trouble on energized line work performed with the hands, the use of 18-inch gauntlet rubber gloves is advocated, and men should be trained to work overhead instead of at a more convenient level. It is ridiculous to sacrifice a practical, logical location for convenience. If a man faints, cuts out, falls, it is better that he fall free of the circuit than into it. It certainly can be said that the rubber glove is the best insurance a man can have, and he has his life in his own hands. In spite of individual and group arguments about the impracticability of using gloves when certain kinds of work are to be performed, it is up to the engineers to devise ways and means in which this work can be done so that while the man is in the primary area he is compelled to leave the protection on his hands.

For working energized circuits with hot sticks, forming the habit of using the sticks at the far end will minimize the chance of the operator reaching out and touching the energized part with his hand or body.

Safety devices are made according to certain specifications and they are not infallible; therefore, men working with these instruments should be re-educated to break down the complacency with which these devices are usually regarded.

The acts of a crew which was in the act of cleaning and painting 110-kv towers emphasize the importance of supervision. Most of the work was being done with the circuit hot, and on a particular type of tower it was found that some tie rods came loose and were to be removed, rethreaded, and replaced. On the morning of the accident a 9-foot tie rod was to be replaced. There was nothing complicated about the job, and it could be handled by two men. The crew was strung out over a mile of line, and the foreman was aware that the one rod was to be replaced; however, he

This is the second of a series of articles on safety. See "Perception of Electric Currents," C. F. Dalziel, T. H. Mansfield (*EE Sep '50*). This is essentially the full text of a conference paper presented at the Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950.

E. C. Hunt is with the Pacific Gas and Electric Company, San Francisco, Calif.

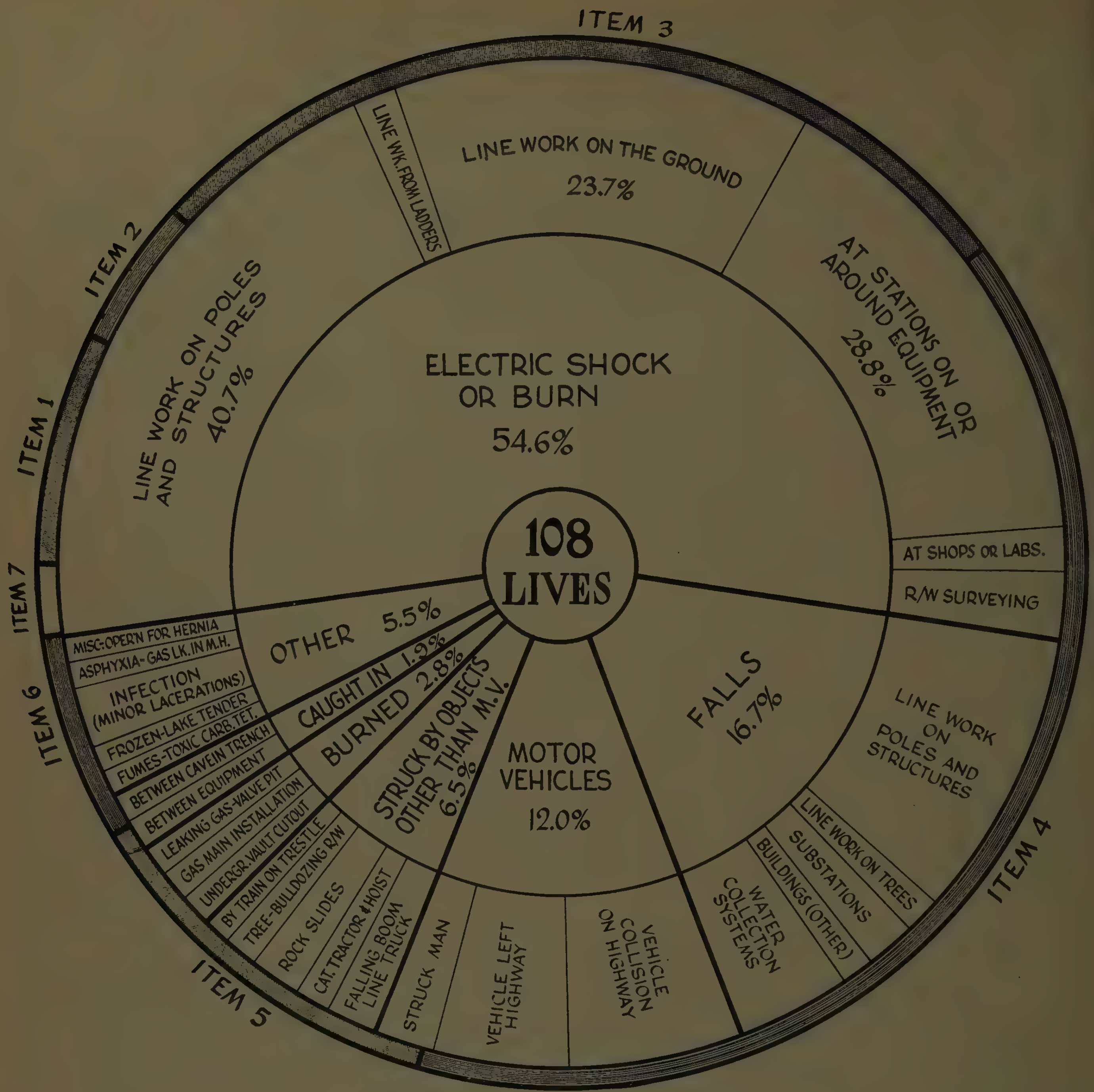


Figure 1. Classification of accidents causing 108 deaths. The rim is a reclassification based on an investigation of accidents

Item 1.	*Direct act of another*	8
Item 2.	*Machine or equipment failure*	5
Item 3.	*Human failure*	30
Item 4.	*Contributory neglect (training, supervision, enforcement)*	43
Item 5.	*Combination (3 plus 4)*	13
Item 6.	*Combination (4 plus 3)*	7
Item 7.	*Not otherwise classified*	2
	Total	108

elected to attend to other duties pertaining to the supervision of the job. The man on the top position on the hot tower raised a 9-foot rod by means of a hand line and then raised it up over his shoulder to get it into place so that his partner below could receive the rod. In raising this rod, contact was made with one phase wire of the 110-kv circuit. The original accident report was filled out placing the fault "with the injured." It was alleged to have been careless to raise a rod and stick it into an energized circuit. If the supervisor had remained at this location for this particular job, he could have very readily prevented this accident.

The 14 cases occurring while line work was being done on the ground will be considered next. Four involved work either while wire was being strung or removed below an energized circuit and men were attending the reel or handling the wire on the ground. Six of the cases involved men who were in touch or contact with the equipment when the boom or winch line came in contact with an energized line. In two cases groundmen were holding the ground cable when a lineman attempted to ground an energized line.

The use of wiring diagrams, study of circuits, knowledge

of the job at hand, and existing field conditions are important. The job should be studied to determine whether it shall be done hot or cold. A definite understanding should be had if the circuit is to be worked hot, and necessary protective devices which are to be made available for the complete job should be used. If the circuit is to be worked cold, the circuit should be de-energized and before anyone reports on the circuit, it should be tested and grounded. The work should be done, wherever practicable, between grounds, or a ground should be established between the workman and every possible source of supply.

Stations. During the period covered in this investigation there were 17 lives lost in station accidents on properties that date back over nearly half a century. Station equipment failures caused two accidents involving three fatal injuries. Facilities that are of old design have not been the direct cause of accidents to personnel, but modern switchgear of today should minimize the possibilities of recurrences of accidents because of human failure. Men going into the wrong circuit or the wrong compartment is a problem which must be overcome in station operation and maintenance.

Of the 17 lives lost in station accidents, two were involved in one accident where there was a failure in a 12-kv bus compartment or cell structure. The exact cause of the fault is still unknown. Double checking and cleaning up the interior of structures during manufacture before the job is buttoned up and energized are important. Stray pieces of metal such as hacksaw blades, welding rods, bolts, steel wool, may contribute to a major fault.

Station employees should use barricades and protective measures the same as linemen. Station employees are complacent about their surroundings and are too familiar with the installation. This is borne out by the greater percentage of 17 cases covering men, certainly well versed in their activity, who were aware of the fact the apparatus they were working adjacent to was energized, and yet inadvertently contacted it to cause their death.

A man lost his life in checking instruments on a panelboard when he came in contact with the open secondary of a current transformer. Test switches would have prevented this type of accident.

Continued improvement in station design should minimize the chances of the individual getting into trouble. In dealing with the human, every step should be taken to keep him on the intended procedure as outlined after careful job planning and briefing before the actual work is started. There should be minimum standards of safeguards and a strict adherence to those standards by everyone. Assumptions should never be made. Written details and schematic diagrams should be made available and the routine of following instructions strictly adhered to. If temporary changes are made in a station, those temporary changes should be incorporated on the operator's diagram and all parties concerned should be notified. If work is to be done adjacent to energized circuits, practical, adequate means should be installed to keep everyone from those energized sections. If this is not practical, closer supervision should be maintained. Men who are not familiar with stations should be guided.

Barricade tape has been presented to industry. This yellow and black tape was introduced to take the place of the old rope to which a flag or a sign was attached. Such ropes were not honored by the men and even supervisors would go beyond them to carry on certain work. This eventually brings on complacency about barricading and sooner or later leads to accident. If a barricade that says "Keep Out" is put up, the ruling should be enforced.

Adequate grounding facilities should always be provided, and the grounding rule as previously outlined followed—work between grounds or have a ground between the man and the possible source of supply. Test before grounding.

FALLS

The classification of falls, which is the next highest, concerns the individual's ability to do his work and his capability of reaching his work. Briefly, the majority of the cases involved persons falling from steel structures; one case, a cutout on a wooden pole; one case, an employee fouled his snap or failed to snap into the D ring; another involved utilization of an old-type safety snap which released from a nonstandard D ring. There was one broken pole.

A lineman has no business in a tree using his regular climbing hooks and safety belt. Tree-trimming work is to be done in the approved manner utilized by tree-trimming companies. Much of the work required by line crews can be reached by means of a ladder. There seems to be a misunderstanding in industry that tree hooks are for all types of trees. A tree hook having a gaff $3^1/_2$ to $4^1/_2$ inches long was originally designed for tree toppers while climbing coniferous trees and was never intended for thin-bark or hard-bark trees.

Supervision plays an important part in minimizing falls. Safety devices should be carefully prescribed with close adherence to standards and constant inspection to maintain such devices in adequate form.

MOTOR VEHICLES

There were 13 fatalities due to motor vehicle accidents. Of the 13, nearly 50 per cent occurred in 1949, and 50 per cent of those were beyond the responsibility of the crew. The remainder of the cases involved human failure because the driver did not recognize the conditions of the road. The traffic situation is getting no better and this menace will continue. Defensive driver consciousness will have to be developed.

STRUCK BY

The "struck by" category accounts for over six per cent of the deaths, and the most outstanding cause is the falling boom. Proper safety pins, safety latches, as well as foolproof operative mechanism for the winch, are necessary to safeguard recurrences of this type of accident.

MISCELLANEOUS

In underground work there was one fatality which was due to the failure of a piece of equipment. It is recommended that underground procedures and safety devices be more closely scrutinized and standard practices be established before more major accidents.

Transverse Flux Induction Heating

R. M. BAKER
MEMBER AIEE

This article describes a special method of induction heating, called transverse flux induction heating, in which the magnetic flux is directed perpendicular to the surface and through the strip instead of along its length, as in longitudinal flux heating.

FOR SEVERAL years following 1941, the author was engaged in the development of radio-frequency induction heating for the flow-brightening of electrolytic tin plate. Lines are in operation today melting the electrolytically deposited tin coating on 30-inch-wide steel strip at speeds of 1,300 feet per minute with a power input of 1,200 kw to the strip. The radio-frequency currents flow in rectangular helical coils around the strip and induce currents in the strip and heat it without contact. The magnetic field and the flux through the coils are directed along the length of the strip and the author chooses to call this method "longitudinal flux induction heating."

During the early stages of this development, it was realized that an equally large potential field for induction heating existed in the heating of nonferrous strip materials like aluminum, brass, magnesium, or stainless steel. It was soon discovered, however, that radio-frequency longitudinal flux induction heating, well suited to heating steel strip, was inefficient and impractical when applied to the heating of nonferrous strip.

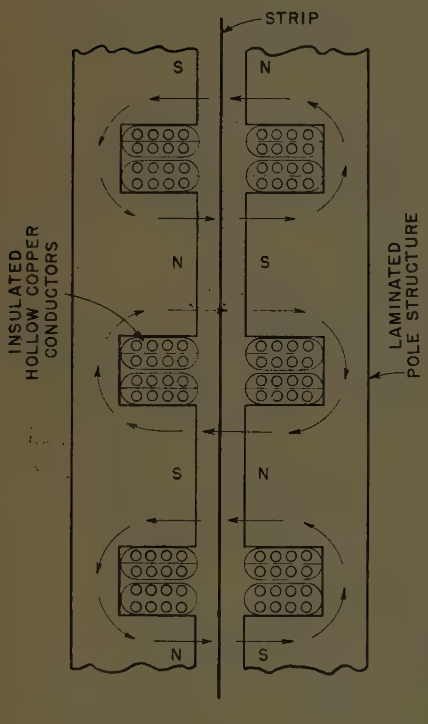


Figure 1. Pole structure and flux path for transverse flux heating

When it was determined that low efficiency of longitudinal flux heating was due to the fact that only a small fraction of the flux through the inducing coil was intercepted by the small cross section of the nonferrous strip, a special and radically different method of induction heating was devised to overcome this difficulty. In this method magnetic flux is directed perpendicular to the surface and through the strip, and the author has chosen to call this method "transverse flux induction heating."

In transverse flux induction heating, the strip passes between two magnetic pole structures as shown in Figure 1. The pole structures are approximately as wide as the strip. The field windings around the poles are supplied with alternating current and so polarized that, at any instant, opposing north and south poles force flux through the strip. The strip acts as a short-circuited turn on a transformer and has currents induced in it as shown in Figure 2. The resistance loss due to these currents produces the desired heating. Since the currents in the strip are more concentrated under the stator slots and less concentrated near the center of a pole, it is obvious that a stationary strip in the air gap would be heated nonuniformly. In a moving strip the heating will be uniform over the entire section, however, because each element of the strip is subjected to the same total heating effect. Some nonuniformity may occur near the edges of the strip but this can be corrected by methods which will be described later in this article.

A mathematical analysis based on certain assumptions shows that the design parameters such as pole pitch l, frequency f, strip thickness t, electric resistivity of strip ρ, and air gap g must be properly related in order to obtain optimum terminal power factor and efficiency. As an example, Figure 3 shows terminal power factor and internal power factor (the latter neglecting slot leakage) as a function of the universal dimensionless parameter kl. In this parameter l is the pole pitch in centimeters and

$$k=\sqrt{\frac{4\pi^2 ft10^{-9}}{\rho g}} \quad (1)$$

where f = frequency (cycles per second), t = strip thickness (centimeters), ρ = electric resistivity of strip (ohm centimeters), and g = air gap (centimeters).

The two curves for terminal power factor are for different slot dimensions, where h = depth of slot (centimeters), and

Essential substance of paper 50-113, "Transverse Flux Induction Heating," recommended by the AIEE Committee on Electric Heating and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

R. M. Baker is with the Westinghouse Electric Corporation, Baltimore, Md.

s = width of slot (centimeters). As seen from Figure 3, terminal power factor is near its optimum value when kl = 2.5. Efficiency is also a maximum at approximately this value o kl. Thus, the optimum design of a transverse-flux coil is summed up in the equation

$$kl=2.5=l\sqrt{\frac{4\pi^2 ft10^{-9}}{\rho g}} \qquad (2)$$

Some discretion must be used in choosing pole pitch in relation to strip width and in choosing slot dimensions relative to pole pitch. As a guide, the author proposes that s/g = 1.0, s/l = 0.25, h/s = 2.0, and b/l = 4.0 or greater (b is the strip width in centimeters). If the pole pitch is too great in comparison to strip width it is difficult to obtain uniform heating across the width of the strip.

The power density induced in the strip is

$$W_a=\frac{2.5gfH_0^2}{t}M(kl)10^{-8}\text{ watts per cubic centimeter} \qquad (3)$$

where M (kl) is a function of kl plotted in Figure 4, and H_0 is the magnetizing force at the edge of a pole pitch calculated from

$$H_0=\frac{0.4\pi(2T_c)I_c}{g}\text{ oersteds} \qquad (4)$$

where T_c = turns in one field coil, and I_c = peak current in a field coil (amperes).

The functions F (kl) and N (kl) shown in Figure 4 are used to calculate internal power factor

$$\text{internal power factor}=\frac{N(kl)}{F(kl)} \qquad (5)$$

Equation 2 can be solved explicitly for optimum frequency to give

$$f_0=\frac{1.58\rho g}{tl^2}10^8\text{ cycles} \qquad (6)$$

Thus it can be seen that the frequency which one chooses depends on the pole pitch and air gap of the pole structure and upon the thickness and electric resistivity of the strip to be heated. Air gaps will vary between one-half inch and several inches, and frequencies will vary from 60 cycles to 10,000 cycles, depending on the job to be done.

With an assembly designed to heat aluminum strip 0.040 inch thick and 54 inches wide, it was possible to choose the pole pitch so as to use a frequency of 60 cycles. Power was taken from shop lines through a suitable transformer. The coil operated with a power input of approximately 300 kw, a power factor of 0.30, and an efficiency of 80 per cent. The air gap was 2.75 inches. A strip speed of 30 feet per minute was obtained with a final strip temperature of 750 degrees Fahrenheit.

This is typical operation from the standpoint of power factor and efficiency, although the frequency and dimensions of the pole structures will differ from job to job.

As mentioned earlier in this article, the movement of the strip through the air gap tends to produce uniform heating everywhere except near the edges of the strip. If the strip is narrower than the pole structures, the edges of the strip overheat. If the strip is much wider than the pole structures, the edges of the strip underheat. It was

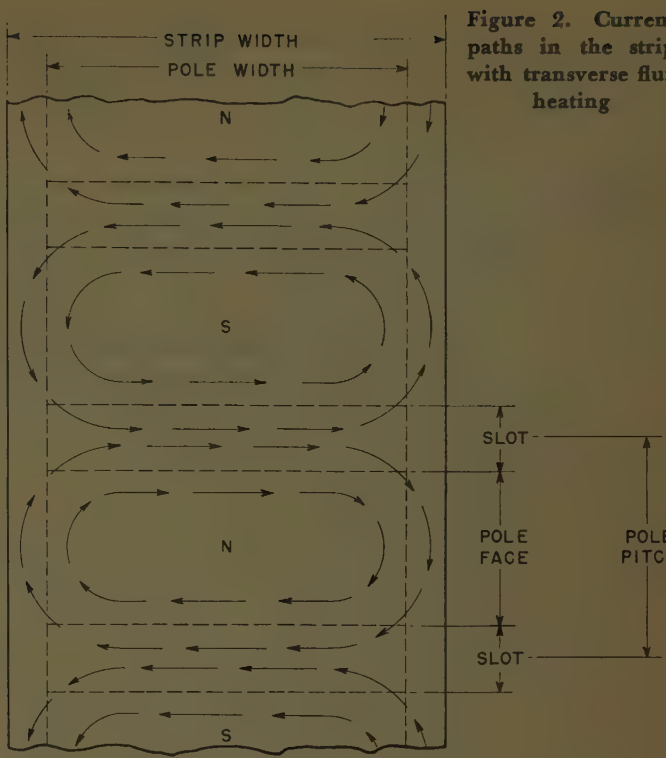


Figure 2. Current paths in the strip with transverse flux heating

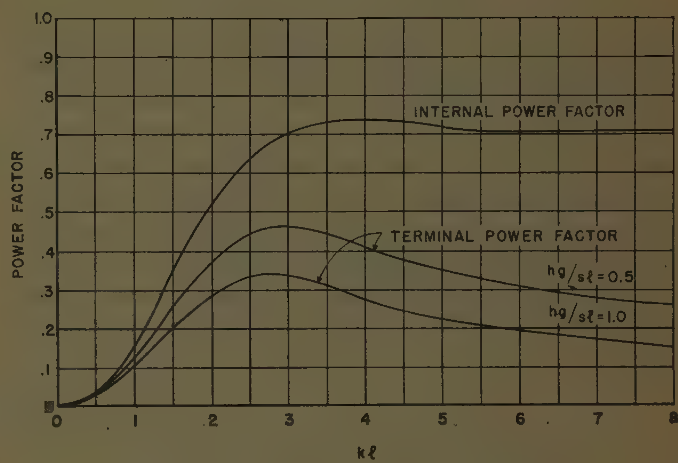


Figure 3. Functions F(kl), M(kl), and N(kl)

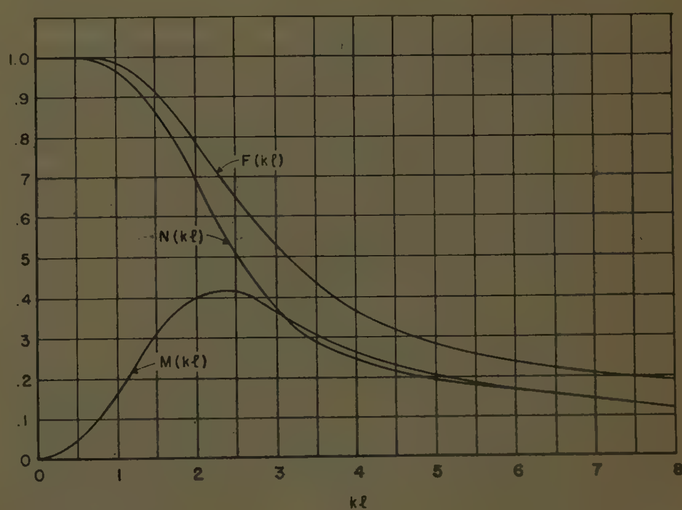


Figure 4. Internal and terminal power factors of field coil

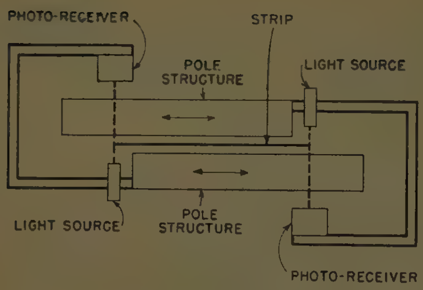


Figure 5. Automatic aligning arrangement for transverse flux coil. Top view

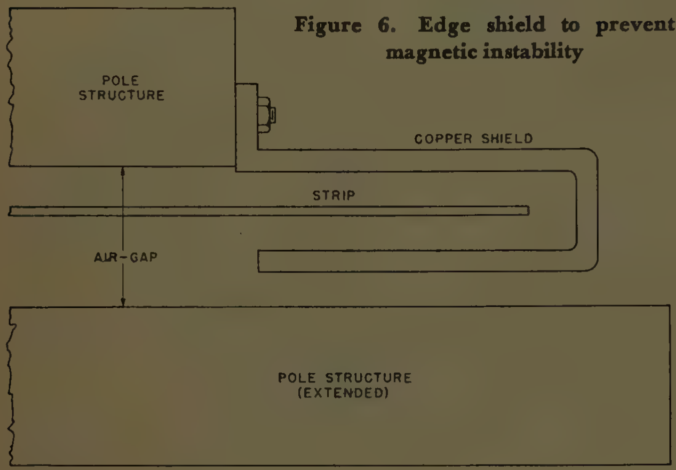


Figure 6. Edge shield to prevent magnetic instability

necessary to find a method for overcoming this difficulty which would be applicable to strips of different widths. A very satisfactory solution was found and is shown schematically in Figure 5. The pole structures are independently mounted on rollers so that their overlapping width can be made just enough less than the strip width to produce uniform heating across the strip. This pole structure was equipped with both vertical and horizontal rollers designed to run on suitable tracks. The pole structures were also equipped with independent photoelectric systems which automatically maintained a fixed distance between the edge of a pole structure and the edge of the strip.

This method proved satisfactory except for one very serious trouble. The current flow near and parallel to the edge of the strip (see Figure 2) tended to pull the edge of the strip down against the iron of the extended pole structure. This was an unexpected and surprising phenomenon, when first observed, because when heating a nonmagnetic strip like aluminum, the tendency near the center of the pole structure is, and should be, one of centering. The peculiar edge effect is explained by the attraction of a current-carrying conductor to a magnetic body near it. A satisfactory solution of this difficulty was obtained by attaching a U-shaped copper shield to the edge of each pole structure, as shown in Figure 6. The shield moves with the pole structure and shields the edge of the strip at all times from the attraction of the pole structure. The thickness of the material from which the shield is made should be equal to, or greater than, the depth of current penetration at the frequency of operation. To minimize losses, a low-resistivity material such as copper should be used.

It is interesting to note that the system of Figures 5 and 6 not only automatically adjusts for strip width, but will also take care of weaving or sidewise motion of a strip.

REFERENCES

1. Induction Heating of Moving Magnetic Strip, R. M. Baker. *Electrical Engineering* (AIEE *Transactions*), volume 64, April 1945, pages 184–9.

2. Heating of Nonmagnetic Electric Conductors by Magnetic Induction, R. M. Baker. *Electrical Engineering* (AIEE *Transactions*), volume 63, June 1944, pages 273–8.

3. Inductive Heating of Longitudinally Moving Metal Strip, R. M. Baker. United States Patent 2,448,009.

4. Induced Heating of Continuously Moving Metal Strip With Pulsating Magnetic Flux, R. M. Baker. United States Patent 2,448,012.

5. Transverse Flux Induction Heating Furnace Structure, R. M. Baker. United States Patent 2,448,010.

6. Method and Apparatus for Induction Heating of Metal Strips, R. M. Baker. United States Patent 2,448,010.

Electrical Essays

Equivalent Networks

"An equivalent network is a network which, under certain conditions of use, may replace another network" (American Standard Definitions of Electrical Terms). If one network can replace another network in some particular system without altering in any way the electrical operation of that portion of the system external to the networks, the networks are said to be "networks of limited equivalence." Examples of the latter are networks which are equivalent only at a single frequency.

A single-phase passive network having two input terminals and two output terminals can be analyzed by any one of five methods. It can be expressed in terms of general circuit constants *A*, *B*, *C*, and *D*, which relate voltage or current at one end of the circuit to both voltage and current at the other end of the circuit. It also can be expressed as an impedance network Z_{11}, Z_{12}, Z_{22} relating each terminal voltage to the two terminal currents. Conversely, it can be expressed as an admittance Y_{11}, Y_{12}, Y_{22} relating each terminal current to the two terminal voltages. Finally, it can be replaced by an equivalent Pi or an equivalent T network.

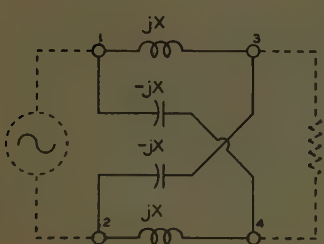


Figure 1. The Steinmetz network

Given the network of Figure 1, which is normally used to supply constant current to a load from a source of constant voltage, the reader is invited to verify the following:

1. Any one of the four elements of the Steinmetz network may be short-circuited without altering in any way the performance of the system external to the network. The Steinmetz network with one element short-circuited is therefore its own equivalent.

2. Any one of the four elements of the Steinmetz network may be removed from the network without altering

in any way the performance of the system external to the network. The Steinmetz network with one element removed is therefore its own equivalent.

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

Surge Impedance?

The engineer from the land of pure electrical constants is investigating a long transmission line which has an impedance per unit length of $z=jx$ and an admittance per unit length of $y=jb$. He calculates the A, B, C, D constants of the line at the frequency at which the line is to operate

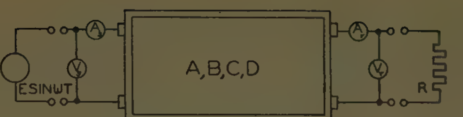


Figure 1

and then assembles the equivalent network in a black box. When $E \sin \omega t$ is applied to the sending end terminals and a resistance R is connected to the receiving end terminals he notes from the measurements, taken as shown in Figure 1, that the ammeters As and Ar give equal readings and the voltmeters Vs and Vr give equal readings. Can it be concluded that R is the surge impedance of the long transmission line?

J. H. DRAKE (A '47)
(Southern California Edison Company, Los Angeles, Calif.)

Draft Status of Students Is Clarified by Selective Service Office

The following statement regarding the draft status of college and university students is presented for the information of AIEE Student members. It comes from the office of Lieutenant Colonel Irving W. Hart, Chief Information Officer, National Headquarters, Selective Service System.

"The Selective Service Act of 1948, as amended, forbids deferment of any group or groups, as such, and provides that each registrant must be classified by his local board on the individual merits of his case in accordance with the Selective Service Law and Regulations.

"The regulations issued under the Act give local boards authority to defer persons whose activity in study, research, or medical, scientific, or other endeavors is found to be necessary to the maintenance of the national health, safety, or interest.

"The Act also gives local boards authority to postpone the induction of college and university students who receive notices of induction after they have started an academic year. The postponement is until the end of the academic year, and the work of the student requesting postponement must be satisfactory.

"That is a postponement of induction as distinguished from a deferment. On August 10 of this year Major General Lewis B. Hershey, Director of Selective Service, sent to local boards an operations bulletin summing up the conditions under which local boards are warranted in considering college students for occupational deferment, pending the development of such other policies as may be necessary.

"These conditions are as follows, and all three must exist to warrant consideration for the deferment:

"1. The registrant has completed at least one academic year of a full-time course of instruction at a college, university, or similar institution of learning.

"2. The college or university at which the registrant last completed an academic year of a full-time course of instruction certifies that the registrant's scholastic standing placed him among the upper half of his class.

"3. The local board is satisfied by the record of the registrant's actions in making normally required arrangements that he had fully intended prior to August 1, 1950, to enroll in a full-time course of instruction at a college, university, or similar institution of learning for the academic year ending in the spring of 1951.

"There is no blanket deferment for students, just as there is no blanket deferment for any group. Each case is decided by the local board on its individual merits in accordance with law and regulations. In no case is a board warranted in considering a student for deferment if the student fails to submit proof that he is doing satisfactory work. Should a deferred student drop out of school, the reason for his deferment ceases to exist, and he is no longer eligible for occupational deferment as a student.

"Selective Service has no jurisdiction over deferment of National Guardsmen and other reservists as such. Policies for deferment of such men who are about to be called to active duty are formulated and administered by the Department of Defense.

"Selective Service is not presently inducting enlisted men or officers who are members of organized reserve components, such as the National Guard, who drill regularly. These men are subject to call to active service with or without their consent under legislation enacted by Congress July 9, 1950. Enlisted men who are members of the inactive reserve—reserves who do not drill—are presently subject to induction by Selective Service, but officers of inactive reserve are not at present.

"Generally speaking, veterans of World War II are not liable for service under the Selective Service Law as presently constituted, except after a declaration of war or national emergency made by the Congress. If a man served honorably a year or more between September 16, 1940, and June 24, 1948, he is not liable for service as a draftee, nor is he liable if he served honorably for more than 90 days during the shooting war—that is, between December 7, 1941, and September 2, 1945. If he served honorably between September 16, 1940, and June 24, 1948, for more than 90 days, but less than a year, he is conditionally deferred if he is in one of the Organized Reserve units."

INSTITUTE ACTIVITIES

Plans Completed, Program Released for 1950 AIEE Fall General Meeting

Arrangements for the 1950 Fall General Meeting of the AIEE, to be held in Oklahoma City, Okla., October 23–27, have been completed, and the tentative technical program released (see pages *928–29*). Headquarters for the meeting will be in the Skirvin Hotel. The technical program is broad in scope and embraces a number of sessions on basic sciences, communication, and power generation.

As the meeting is being held in an area surrounded by oil-bearing lands, two sessions will be devoted to papers on oil industry applications. A third session has been arranged on the subject of large-scale computing devices and their application to the chemical and petroleum industry, and papers appropriate to the Middle West will also be presented on applications in the mining and metal industries. In addition, a session is scheduled in which papers will consider the theory and application of cathodic protection.

The general session on Tuesday morning will be opened by Roy J. Turner, Governor of Oklahoma, who will welcome the AIEE. Dr. H. G. Bennett, President of Oklahoma Agricultural and Mechanical College, will address the session on "The Obligation of World Leadership," while AIEE President T. G. LeClair will consider the question, "Are You an Engineer?" H. R. Fritz, Vice-President of AIEE District 7, is also on the general session agenda.

ENTERTAINMENT

On Tuesday evening, the Stag Smoker will be held in the Convention Hall of the Skirvin Hotel. This traditional event is being planned so that old friendships may be renewed and new friends acquired. A fine buffet dinner supplemented by good entertainment is being planned so that an enjoyable evening may be had by all.

The highlight of the week's entertainment is expected to be the traditional dinner-dance which is scheduled for Wednesday evening. The floor show will include a variety of numbers, one of which is a program of songs presented by the Oklahoma City University Chorus. Another number of special interest will be dances presented by a square dance group in colorful costumes. The show will be followed by dancing until midnight. Dress is optional.

A Fluid Mapper Program will be given by Professor A. D. Moore on Thursday evening. Developed by Professor Moore largely during the past two years, the devices he has called fluid mappers cause streamline fluid flow to give visual simulations of electrostatic, electromagnetic, heat conduction, and other analogous fields. The flow patterns can be analyzed, thus leading to solutions of field problems. (See *Electrical Engineering, July '50, pp 607–10*).

Professor Moore's invention of the sand-bed as a distributed fluid source carries fluid mappers into the realm of the extremely complicated phenomena found within distributed space charges, distributed currents, and the like. Fluid mappers may also be built to handle some cases having axial symmetry.

During the program on Thursday evening an artificial stone slab will be cast, and operated in a fluid mapper. Many color slides of the beautiful flow patterns will be shown. Fluid Mapper Programs already given by the speaker to industrial and government research groups and various other groups have invariably stimulated very great interest.

Another interesting event is being planned for Friday noon when a joint luncheon with the Oklahoma City Chamber of Commerce Friday Forum will be held in the Skirvin Tower Hotel Persian Room. The luncheon will feature an address by President LeClair who will speak on the topic, "What Engineers Do For Your Business."

LADIES' PROGRAM

Parlor 1012 in the Skirvin Hotel has been reserved as Ladies' Headquarters. There will be hostesses present at all times to extend a welcome and here the ladies may enjoy a game of cards, or obtain information.

Mustang Generating Station of the Oklahoma Gas and Electric Company under construction west of Oklahoma City, site of the 1950 AIEE Fall General Meeting

Future AIEE Meetings

Middle Eastern District Meeting
Lord Baltimore Hotel, Baltimore, Md.
October 3–5, 1950
(*Final date for submitting papers—closed*)

AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine
Park-Sheraton Hotel, New York, N. Y.
October 23–25, 1950

Fall General Meeting
Skirvin Hotel, Oklahoma City, Okla.
October 23–27, 1950
(*Final date for submitting papers—closed*)

Conference on Electrical Engineering in the Machine Tool Industry
Worcester, Mass.
November 15–17, 1950 (rescheduled from October 11–13)

Conference on High-Frequency Measurements
Hotel Statler, Washington, D. C.
January 10–12, 1951

Winter General Meeting
Hotel Statler, New York, N. Y.
January 22–26, 1951
(*Final date for submitting papers—October 24*)

Southern District Meeting
Miami, Fla.
April 11–13, 1951
(*Final date for submitting papers—January 11*)

North Eastern District Meeting
Syracuse, N. Y.
May 2–4, 1951
(*Final date for submitting papers—February 1*)

Great Lakes District Meeting
Madison, Wis.
May 17–19, 1951
(*Final date for submitting papers—February 16*)

Summer General Meeting
Royal York Hotel, Toronto, Ontario, Canada
June 25–29, 1951
(*Final date for submitting papers—March 27*)

Pacific General Meeting
Portland, Oreg.
August 20–23, 1951
(*Final date for submitting papers—May 21*)

On Monday afternoon, chartered busses will take the ladies to the Oklahoma Historical Building on the State Capitol grounds where an interesting program enriched by Oklahoma's colorful Indian history will be presented. On Tuesday morning, they will again board the busses for a tour of the city, stopping at the Oklahoma City Country Club for brunch. For Tuesday evening, dinner, bridge, and canasta are planned at the Beacon Club atop the First National Building overlooking Oklahoma City.

On Wednesday, the ladies will make a tour of the art center at the Civic Center, and on Thursday a buffet luncheon and style show is scheduled for the Hotel Skirvin's Crystal Room. In the evening the men will be the ladies' guests for bridge and canasta in the Venetian Room.

SPORTS

Arrangements have been made for registered members and their guests to play golf. Transportation will be provided and must be arranged for at the Sports Registration Desk in advance. Tickets must also be obtained at the desk in advance by those who wish to play.

Night view of Oklahoma City Civic Center facing west

INSPECTION TRIPS

The following inspection trips have been scheduled during the 1950 Fall General Meeting. Admission will be by ticket only and it is extremely important that members and their guests obtain these tickets at the Inspection Trip Desk as soon as possible upon their arrival.

Trip 1. A tour of the Oklahoma City oil fields and contiguous territory to show a rotary drilling rig in operation, natural gasoline plants, electric-powered oil pumping stations, several types of electrically pumped oil wells, and a general view of oil wells located on the State Capitol Building's grounds. The tour, which will cover 20 miles, will take about two hours, and is scheduled for October 25 and 26, at 2 P.M.

Trip 2. A tour of the mechanical production plant of the Oklahoma Publishing Company (the printers of the *Daily Oklahoman* and *Times*) showing electrically operated and controlled presses, stereotype machinery, and wire photo service. This is one of the most modern newspaper publishing plants in the nation. Tour will take about $1^1/_2$ hours, on October 23 and 26, 4:30 P.M.

Trip 3. An inspection trip will be arranged covering the Belle Isle generating station of the Oklahoma Gas and Electric Company. The feature interest at this station is the first commercial installation of a gas turbine unit applied to electric generation. This unit has been in service since July 1949, and has been phenomenally successful both as to dependability and performance. It has attracted international attention and will be seen in actual operation.

This tour will also include the Mustang Station which consists of two 50,000-kw steam turbogenerating units operating at 850 pounds per square inch at 900 degrees Fahrenheit. One of these units has been in operation since May 1950, and the second unit will be placed in operation about January 1951. This tour will consume approximately three hours and involve bus travel of about 25 miles. It is scheduled for October 24, 25, and 27, at 2 P.M.

Trip 4. This tour is to Tinker Air Force Base, the largest Air Force depot of the United States Department of Defense. Objects of interest will include the only jet engine overhaul assembly line in any of the Air Force depots; a closehand view of the overhaul of the *R-3350* airplane engine used in *B-29*'s; and a close-up inspection of the Air Force's larger bombers. Also, a tour of the commanding general's control room will be made and a lecture in the auditorium will be provided by the commanding officer, Major General F. S. Borum, on "What Goes on in an Air Depot." This activity employs more than 15,000 people and the electric load approximates 10,000 kw. The tour, by bus, will take approximately three hours, and is scheduled to cover about 25 miles. It will take place on October 23 and 27, at 2 P.M.

Trip 5. A tour through the downtown Oklahoma City Building of the Southwestern Bell Telephone Company will afford an opportunity for members to see in operation a large communication center. The inspection party will see the following: the terminal of the buried intercity long-distance cables from the east to south; facility for local exchange telephone service; equipment and switchboard for originating, terminating, and "through" long-distance telephone traffic; information and intercepting switchboards; facilities for providing and monitoring radio program network service; facilities for telegraph and leased wire service; a switching center for teletypewriter exchange service; facilities and switchboard positions for mobile radio-telephone service; a modern test center. The tour will take place on October 24 at 2 P.M., and October 25 at 4:30 P.M.

Trip 6. A tour, on Monday at 8 P.M., through the studio of *WKY-TV* television station will be of interest to the ladies as well as the members. *WKY-TV* was the pioneer television station in the state. The entire station will be inspected including studios, control rooms, transmitter rooms, and movie projection rooms. Cameras and other equipment will be operated in full view of the audience. A balcony is available for the visitors to view live broadcasts and see and hear a program in the actual process of being televised.

HOTEL RESERVATIONS

All requests for room reservations should be sent directly to R. L. Jones, Chairman, Hotel Committee, 1101 Telephone Building, Oklahoma City, Okla. Members are urged to send in their room requests early by completing the "Hotel Accommodation" card contained with the mailed announcement. All room reservations available at the Skirvin are now exhausted and future reservations will be filled at the Biltmore, Wells Roberts, Huckins, Black, Sieber, or Park-O-Tel. The latter two are auto-type courts with car parking facilities. Room rates per day will be approximately as follows:

Single room	$4.00 to $6.00
Double room, double bed	6.00 to 8.50
Double room, twin beds	6.50 to 8.50
Suites	8.00 to 25.00

All rooms are with bath.

Reservations are made for the night of October 22 and should be vacated by Friday evening, October 27, unless other arrangements are made.

REGISTRATION

Advance registration cards contained with the mailed announcement should be mailed as promptly as possible to J. A. Taylor, Chairman, Registration Committee, 1950 Fall General Meeting, AIEE, General Electric Company, 1106 Perrine Building, Oklahoma City 2, Okla.

In accordance with the policies as set up by the Board of Directors, a registration fee of $3 will be required of members and a fee of $5 for nonmembers. This is to help make the meeting self-supporting and obviate the

(*Continued on page 930*)

Tentative Technical Program

Fall General Meeting, Oklahoma City, Okla., October 23-27

Monday, October 23

9:30 a.m. Conductor Vibration

50-237. Vibration and Fatigue Life of Steel Strand. *J. C. Little, D. G. MacMillan, J. V. Majercak,* American Steel and Wire Company

50-278. Use of Techniques From Electrical Analogues in the Study of Transmission Line Vibration. *Jordan Lummis, Arthur Klopfenstein,* Southern California Edison Company

CP. BPA Experience With Conductor Vibration.** *M. B. Elton, A. A. Osipovich, M. G. Poland,* Bonneville Power Administration

CP. Vibration—Symposium.** *E. L. Kanouse,* Department of Water and Power, The City of Los Angeles

CP. Failures of Overhead Ground Wires Caused by Aeolian Vibration.** *P. G. Wallace,* Texas Power and Light Company

CP. Experience and Remedial Measures for Failures of Overhead Ground Wires Caused by Aeolian Vibration.** *R. F. Danner,* Oklahoma Gas and Electric Company

CP. Vibrations—Review of Experiences—1950.** *L. M. Robertson,* Public Service Company of Colorado

CP. Dampers—Torsional—Experience in Canada During Ten Years.** *J. H. Waghorne, A. D. Hoff, T. J. Burgess,* Hydro-Electric Power Commission of Ontario

CP. Aeolian Vibration Combines With Galloping to Speed up Failures in Conductors.** *A. E. Davison,* Hydro-Electric Power Commission of Ontario

CP. Report of Progress in Conductor Vibration Investigations.** *Joel Tompkins,* Aluminum Company of America

9:30 a.m. Conference on Energy Sources

CP. Ultrasonic Waves in Air.** *R. W. Armstrong,* Evans Signal Laboratory

CP. Aerodynamics of the Power Wind Tunnel.** *P. H. Thomas,* Montclair, N. J.

CP. Limitations of Prime Movers.** *W. P. Green.* Illinois Institute of Technology

9:30 a.m. Moderate Haul Telephone and Television Systems

50-235. A Negative Impedance Repeater. *J. L. Merrill, Jr.,* Bell Telephone Laboratories, Inc.

50-240. A Simplified 48-Channel Carrier Telephone System. *L. R. Erickson,* Lenkurt Electric Company

50-241. An Improved Transmitted Carrier System for Telephone Lines of Short or Medium Length. *G. H. Brodie,* Kellogg Switchboard and Supply Company

50-242. A Medium-Haul Carrier Telephone System. *H. H. Smith,* Federal Telephone and Radio Corporation

50-234. Local Wire Video Television Networks. *C. N. Nebel,* Bell Telephone Laboratories, Inc.

2:00 p.m. 69-Kv Transmission Line Design Practices

50-243. Light Steel Tower Line Designs. *A. A. Osipovich,* Bonneville Power Administration

CP. Line Structures for 66,000 Volts, an Established Sub-Transmission Voltage in New England.** *C. A. Booker,* New England Power Service Company.

CP. 69-Kv Review of Experience Types Used—Accumulated Experience and Preferred Types With Reasons.** *J. E. O'Brien,* Rural Electrification Administration

CP. Sagging Conductors in Incline Spans.** *H. H. Rodee,* Aluminum Company of America

CP. Current Loadings for ACSR Conductors—1950.** *A. S. Runciman,* Shawinigan Water and Power Company

CP. Bolometers—Two Years' Experience in Field Locating Hot Joints.** *J. Leslie,* Hydro-Electric Power Commission of Ontario

2:00 p.m. Basic Science

50-246. Transpositions and the Calculation of Inductance From Geometric Mean Distances. *W. B. Boas*, Iowa State College

CP. A Set of General Electrical Formulas.** *V. P. Hessler,* University of Illinois; *D. D. Robb,* Iowa State College

50-245. Transients in Coupled L-C Circuits Analyzed in Terms of a Rolling-Ball Analogue. *P. C. Magnusson,* Oregon State College

50-244. Steady-State Waves on Transmission Lines. *D. L. Waidelich,* University of Missouri

2:00 p.m. Communication Switching Systems

50-247-ACO.* The Leich Electric Dial Switchboard. *H. G. Evers,* Leich Electric Company

50-227. Simplified Subscribers Toll Dialing for Low Rate, Low Density Toll Circuits Between CDO'S. *Eric Brooke, J. M. Blackhall, W. H. Blashfield,* The North Electric Manufacturing Company

50-248. Dial Central Office Buildings for Small Communities. *F. D. Reese, E. C. Roys,* Pennsylvania Telephone Corporation

50-249. General Aspects of Community Dial Office Equipment. *A. Burkett,* Bell Telephone Laboratories, Inc.

Tuesday, October 24

10:00 a.m. General Session

Welcome to Oklahoma. Honorable Roy J. Turner, Governor of Oklahoma
For the Seventh District, H. R. Fritz, Vice-President, District 7, AIEE
General Announcements. W. B. Stephenson, Chairman, 1950 Fall General Meeting
"The Obligations of World Leadership." Dr. H. G. Bennett, President, Oklahoma Agricultural and Mechanical College
"Are You an Engineer?" T. G. LeClair, President. AIEE

2:00 p.m. Transmission and Distribution

50-250. Some Aspects of Lightning Surges on Power Systems and Their Suppression. *S. Kaneff,* The University of Adelaide

50-224. Practical Experiences With Resonant Grounding in a Large 34.5-Kv System. *H. H. Brown,* Wisconsin Michigan Power Company; *E. T. B. Gross,* Illinois Institute of Technology

CP. Determination of Resistance to Ground of Grounding Grids.** *A. J. McCrocklin, Jr., C. W. Wendlandt,* The University of Texas

50-251. Nine-Year Operating Record of Rural Line Sectionalizing by Repeater Fuses. *R. M. Schahfer,* Northern Indiana Public Service Company

50-236. Effect of 3-Phase Motor Loads on Voltage Changes Produced by Single-Phase Loads. *M. A. Faucett, M. Fisher, Jr., M. S. Helm,* University of Illinois

CP. Supervisory Control for 13.8-Kv Tie Feeders.** *R. A. Williams,* Arkansas Power and Light Company; *V. B. Wilfley,* Westinghouse Electric Corporation

2:00 p.m. Rotating Machinery

50-252. Synchronous Machine Damping Torque at Low Speeds. *Charles Concordia,* General Electric Company

50-253. Symmetrical Short Circuits on Saturated Alternators. *S. L. Mikhail,* Cambridge, Mass.

50-254. An Experimental and Analytical Study of Turbine Rotor Ventilation. *C. J. Fechheimer,* Milwaukee, Wis.

50-232. A Method of Total Design as Applied to Polyphase Induction Motors. *C. H. Crouse,* Robbins and Myers, Inc.

50-255. The Goerges Phenomenon—Induction Motors With Unbalanced Rotor Impedances. *H. L. Garbarino,* General Electric Company; *Eric T. B. Gross,* Illinois Institute of Technology

2:00 p.m. Mining and Metal Industries

CP. Electrical Applications in Mining—Southeast Missouri Division—Saint Joseph Lead Company.** *Bert L. Beal, Jr.,* St. Joseph Lead Company

CP. Automatic Hoisting.** *H. A. London, R. D. Call,* Westinghouse Electric Corporation; *A. B. Chafetz,* International Minerals and Chemical Corporation

CP. Use of Electricity in Bauxite Mining.** *E. A. Brenn,* Alcoa Mining Company

50-230. Electrical Equipment for Heavy Media Separation Process. *J. J. Bean,* American Cyanamid Company; *K. A. Blind,* Dings Magnetic Separator Company. Presentation by title only

Wednesday, October 25

9:30 a.m. Insulated Conductors

50-256. Critical Inside Dimensions for Power Cable Manholes. *E. S. Halfmann,* Philadelphia Electric Company

50-257. Underground Conduit for Electric Power Systems-Fundamentals and Basic Design Considerations. *E. G. Watkins,* Consolidated Edison Company of New York, Inc.

50-258. Terminal Risers for Solid-Type Impregnated Paper Cables. *W. A. Del Mar,* Phelps Dodge Copper Products Corporation

9:30 a.m. Conference on Effect of Low Voltage and Low Frequency on Power Plant Auxiliaries

CP. Interruption of Service of the San Antonio Electrical System.** *H. C. Hughes,* City Public Service Board, San Antonio, Texas

CP. The Effect of Voltage and Frequency Reduction on Steam Plant Operation.** *T. W. Schroder,* Iowa Power and Light Company

CP. Design and Operation of Generating Station Auxiliaries for Power System Reliability.** *W. R. Brownlee, J. A. Elzi,* Commonwealth Associates, Inc.

CP. Supply Systems for Havana and Woodriver Station Auxiliaries.** *E. R. Walton,* Illinois Power Company; *S. L. Chapin,* Sargent and Lundy

CP. Effect of System Frequency on Plant Capacity.** *H. A. Bauman, G. R. Hahn, C. N. Metcalf,* Consolidated Edison Company of New York, Inc.

50-280. Determination of Reserve Capacity by the Probability Theory—II *G. Calabrese,* New York University. Presentation by title only

9:30 a.m. Large-Scale Computing Devices and Their Application to the Chemical and Petroleum Industry

CP. Automatic Computing Machines and Devices.** *C. C. Hurd,* International Business Machines Corporation

CP. The Use of IBM Punched Card Devices for Distillation Calculations.** *Arthur Rose, T. J. Williams,* Pennsylvania State College

50-259-ACO.* Application of Automatic Digital Computing Methods to the Prediction of Phase Behavior. *T. J. Connolly, S. P. Frankel, B. H. Sage,* California Institute of Technology

CP. Applications of the Multicomponent Fractionation Electric Analogue Computer.** *G. M. Brown,*

---

*ACO: Advance copies only available; not intended for publication in *Transactions.*

**CP: District paper; no advance copies are available; not intended for publication in *Transactions.*

J. H. Ashley, J. J. Moder, G. W. Goelz, Northwestern University

CP.** Solution of Fluid Flow Problems on the Anacom. *J. T. Carleton*, Westinghouse Electric Corporation

2:00 p.m. Symposium on Totally Enclosed Motors

CP. The Totally Enclosed Fan-Cooled Enclosure as Applied to Squirrel-Cage Induction Motors.** *D. H. Ware*, General Electric Company

50-260–ACO.* Copper Fin Totally Enclosed Motors. *L. A. Killgore, J. F. Heidbreder*, Westinghouse Electric Corporation

50-228–ACO.* Large Tube Type, Totally Enclosed Fan-Cooled Motors. *R. C. Moore*, Allis-Chalmers Manufacturing Company

CP. Large Motors for Powerhouse Auxiliaries.** *Quentin Graham*, Elliott Company

50-229–ACO.* Trends in Auxiliary Motor Applications in Steam Electric Stations. *H. L. Lowe*, Ebasco Services, Inc.

50-226–ACO.* Totally Enclosed Auxiliary Drive Motors for Generating Stations. *J. G. Noest*, Consolidated Edison Company of New York, Inc.

2:00 p.m. Industrial Power Systems

50-261. Automatic Control of Metalclad Switchgear Serving Oil Refinery Motors During Power System Disturbances. *R. T. Horsfall*, Dingle Clark Company; *K. N. Thompson, R. W. Mills*, Standard Oil Company of Ohio; *P. O. Bobo*, Westinghouse Electric Corporation

CP. Electric Oil Pumping.** *W. C. Dreyer, F. K. Smith*, Westinghouse Electric Corporation

CP. Industrial Power Networks.** *H. D. Hughes*, Stanolind Oil and Gas Company; *W. H. Rollman*, Westinghouse Electric Corporation

CP. Speaking of Electric Distribution System Expansion.** *H. C. Swannell*, J. E. Sirrine Company

2:00 p.m. Computing Devices

50-262–ACO.* Design Objectives of the NRL Electronic Digital Computer. *D. H. Gridley, B. L. Sarahan*, Naval Research Laboratory

CP. Problem Preparation for a Digital Computer.** *D. H. Gridley, B. L. Sarahan, J. S. Seward*, Naval Research Laboratory

50-215. Special Devices Aid Differential Analyzer Solution of Complex Problems. *A. C. Cook, L. K. Kirchmayer*, General Electric Company; *C. N. Weygandt*, University of Pennsylvania

50-263. An Electric Analogue Computer, Using the Photocell as a Nonlinear Element. *E. C. Koenig*, Allis-Chalmers Manufacturing Company

Thursday, October 26

9:30 a.m. Symposium on Supervisory Instruments

50-264–ACO.* The Supervisory Instrument—Its Contribution to Centralized Control. *T. T. Frankenberg*, American Gas and Electric Service Corporation

50-221–ACO.* Instruments for Detection of Toxic and Explosive Gases. *N. W. Hartz*, Mine Safety Appliances Company

50-265–ACO.* Improving Surface Condenser Performance Through the Use of Supervisory Instruments. *J. G. Dobson*, The Foxboro Company

50-218–ACO.* High-Speed Supervision of Process Variables. *W. E. Belcher, Jr.*, Minneapolis-Honeywell Regulator Company

50-223. Centralized Control Board for Steam-Electric Generating Plants. *H. L. Lowe*, Ebasco Services, Inc.; *R. L. Hodgkins*, General Electric Company

9:30 a.m. Electronic System Engineering

CP. Some Engineering Aspects of the Mechanism of Body Control.** *Robert Mayne*, Goodyear Aircraft Corporation

50-266. Information Theory Applied to System Design. *W. G. Tuller*, Melpar, Inc.

CP. Air-Borne Antisubmarine Systems.** *T. B. Schillo*, Glenn L. Martin Company

CP. A Special Purpose Analogue Computing System for the Radar Triangulation Problem.** *R. E. Langworthy, R. M. Byrne*, Goodyear Aircraft Corporation

50-267. The Further Development of Fluid Mappers. *A. D. Moore*, University of Michigan

9:30 a.m. Conference on Cathodic Protection

CP. Various Cathodic Protection Applications Using Graphite Anodes.** *J. P. Oliver*, Union Carbide and Carbon Corporation

CP. Sources of Power for Cathodic Protection.** *F. F. Knapp*, Montana-Dakota Utilities Company

50-279–ACO.* Cost Study of Generation of 80,000 Kw of D-C Power from Natural Gas. *J. R. Smith, F. L. Kaestle*, General Electric Company

2:00 p.m. Power Generation

50-222. Induced Currents in High-Capacity Bus Enclosures. *S. C. Killian*, Delta-Star Electric Company

50-268. Continuous Scavenging System for Hydrogen-Cooled Generators. *D. S. Snell, L. P. Grobel*, General Electric Company

50-269. Control of Gas Turbines for Power Generation. *D. C. Hoffmann, A. G. Mellor, N. E. Starkey*, General Electric Company

50-270. Thrust Bearing Problems and Their Solution on Turbine-Generator Units and Auxiliaries of the Consolidated Edison System. *J. M. Driscoll*, Consolidated Edison Company of N. Y., Inc.; *H. C. Otten*, The Yonkers Electric Light and Power Company

2:00 p.m. Switchgear

50-271. An Air Delayed Selective Overcurrent Tripping Device for Low-Voltage Air Circuit Breakers. *B. G. Tremblay, M. E. Horn*, Westinghouse Electric Corporation

50-272. New Low-Voltage Air Circuit Breaker With 50,000 Amperes Interrupting Capacity at 600 Volts Alternating Current. *M. E. Horn, J. J. Mikos*, Westinghouse Electric Corporation

---

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

50-239. Ice Testing of Outdoor Disconnecting Switches to Simulate Field Conditions. *J. B. Owens*, Westinghouse Electric Corporation

Friday, October 27

9:30 a.m. Relays

50-233. A Study of Directional Element Connections for Phase Relays. *W. K. Sonnemann*, Westinghouse Electric Corporation

50-238. An Improved Reclosing Relay. *L. E. Goff*, General Electric Company

CP. The Conference for Protective Relay Engineers, Texas A&M College.** *L. M. Haupt*, Agricultural and Mechanical College of Texas

CP. Operating Experience With Ground Distance Relays.** *M. P. Osburn, P. L. Dandeno*, Hydro-Electric Power Commission of Ontario

9:30 a.m. Feedback Control Systems

50-231. Stability of Voltage Regulators. *F. E. Bothwell*, The University of Chicago

50-274. Stability of Servos Whose Elements Vary Linearly With Time. *M. J. Kirby*, Sperry Gyroscope Company

CP. System Frequency Response Derived From Transient Response.** *A. R. Teasdale, Jr., F. E. Brooks, Jr., J. P. German*, The University of Texas

CP. Transient Analysis of Servomechanism.** *Andrew Vazsonyi*, United States Naval Ordnance Test Station

50-219. Integral Controller for Use in Carrier-Type Servomechanisms. *R. L. Cosgriff*, Curtiss-Wright Corporation

9:30 a.m. Oil Industry Applications

CP. Application of Electric Motors in the Oil Pumping Industry.** *T. C. Lloyd*, Robbins and Myers, Inc.

CP. Design and Application of A-C Motors for Crude Oil Production.** *G. A. Smith*, Shell Oil Company

CP. How the Petroleum Industry Uses Electric Power.** *W. H. Stueve*, Oklahoma Gas and Electric Company

CP. Application of Electricity in Exploration for Petrolum.** *L. B. Blalock*, Texas Power and Light Company

2:00 p.m. Transformers

50-220. Single-Phase Power Transformer Formed Cores. *T. D. Gordy, G. G. Somerville*, General Electric Company

50-225. Transformer Noise and Its Confinement. *Corbett McLean*, Pacific Power and Light Company

50-216. Economical Design of a 3-Phase Transformer. *Ladislav Cigánek*, Bratislava, Czechoslovakia

50-275. Variations of Tank Pressure With Transformer Loading in Sealed Transformers. *E. W. Tipton*, Westinghouse Electric Corporation

50-217. Control Circuit Transformers. *J. M. Frank, A. J. Hauck*, Hevi Duty Electric Company. Presentation by title only

50-273. Contributing Factors in Determining the Ratings of Power Transformers for Use on the Systems of the Hydro-Electric Power Commission of Ontario. *D. B. Fleming, J. S. Lotimer*, The Hydro-Electric Power Commission of Ontario. Presentation by title only

2:00 p.m. Oil Industry Applications

CP. Application of A-C Motors to Oil Well Pumping.** *Max Halderson*, Phillips, Bartlesville

CP. Selection of the Electric Motors for Oil Well Beam Pumping,** *J. N. Poore*, General Electric Company

CP. Development and Operation of Reda Submergible Pumps.** *Joe Carle*, Reda Pump Company

CP. Electric Oil Pumping.** *W. C. Dreyer, F. K. Smith*, Westinghouse Electric Corporation

CP. Application of Capacitors in Oil Field Production.** *W. B. Helms*, Southwestern Public Service Company; *W. R. Horrigan*, C. B. Anderson Company

Fall General Meeting

(*Continued from page 927*)

need for raising the annual dues. Student members and the immediate families of members will not be required to pay any fee. Do not enclose remittance with advance registration. Fees will be collected when registering.

GENERAL INFORMATION

Information on all features may be obtained at the Registration Desk. The table for mail and memoranda will be maintained as well as a special bulletin board for posting of personal messages and notices. Schedule of inspection trips and entertainment features will also be displayed.

MEETING COMMITTEES

Members of the Fall General Meeting Committee making arrangements are: W. B. Stephenson, Chairman; R. F. Danner, Vice-Chairman; Frank Meyer, Vice-Chairman; Ralph Randall, Vice-Chairman; M. C. Reed, Secretary.

The chairmen of the various subcommittees are: Sim Wright, Publicity; Bryce Brady, Program; Mrs. R. F. Danner, Ladies; Otis Howard, Inspection Trips; R. L. Jones, Hotel; J. S. Joseph, Sports; George Larason, Entertainment; J. A. Taylor, Registration; J. S. Wantland, Finance.

Nucleonics and Medicine to Be Featured at Electronic Instrumentation Conference

"The Effects of Atomic Weapons," the Government's recently issued guide book for the preparation of civil defense measures against atomic attack, is to be the subject of an evening round-table discussion by prominent authorities in the field during the Third Annual Joint AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine, which is to be held October 23–25, 1950, at the Park Sheraton Hotel, New York City. During the evening of October 24th, Brigadier General James P. Cooney, Chief, Radiological Branch, Division of Military Application, Professor H. L. Bowman of Drexel Institute, consultant to the Atomic Energy Commission, and Dr. Herbert Scoville, Armed Forces Special Weapons Project, will discuss techniques of protection from the effects of atomic weapons.

Over 800 people are expected to attend the 3-day conference which includes a program of some 25 papers. Recent advances in the application of electronic instruments in the field of medicine will be covered during the first day's sessions. The second day's group of papers is devoted to subjects of interest to both the engineering and medical professions. Engineering aspects of instrument design and manufacture for nucleonic and medical use is the subject of the third day's sessions. A consolidated pamphlet which will include the papers and discussions presented will be published and made available after the conference has been held.

During the last two days of the conference, leading companies will have on display interesting and informative exhibits of instruments and related products, making it possible for those attending the meeting to see many of the devices (some in actual operation) which will be discussed in the technical papers.

Revised Copies Available of Welding Bibliography

According to a recent announcement, the "Bibliography on Power Supply for Electric Welding" has been revised to include references for the year 1949. Persons interested in obtaining copies may do so by sending their orders to AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Prices of the revised bibliography are 30 cents per copy to members of the AIEE and 60 cents per copy to nonmembers.

Program

Third Annual Joint AIEE–IRE Conference on Electronic Instrumentation in Nucleonics and Medicine

October 23–25, 1950

Monday, October 23

Morning Session

The Needs of Physiology and Medicine for Better Instrumentation for the Measurement of Respiratory Gases. *Wallace O. Fenn*, Professor of Physiology, University of Rochester

Analysis of Respiratory Gases With Mass Spectrometer. *Fred A. Hitchcock*, Department of Physiology, Ohio State University

The Application of the Infrared Spectrophotometry to the Analysis of Respiratory Gases. *E. D. Palmes*, New York University, Bellevue Medical Center, New York

The Measurement of Oxygen in Gases by Paramagnetism. *Arnold O. Beckman*, South Pasadena, Calif.

Afternoon Session

The Delineation of Intracranial Structure With the Aid of Ultrasonic Waves. *R. H. Bolt, H. T. Ballantine, G. R. Ludwig, T. E. Hueter*, Acoustics Laboratory, Massachusetts Institute of Technology

The Localization of Brain Tumors With Radioactive Isotopes. *Theodore Fields*, Veterans' Hospital, Hines, Ill.

The Use of Isotopes in the Measurement of Body Fluids. *John L. Nickerson*, Professor of Physiology, College of Physicians and Surgeons, Columbia University

Developing of Sectioning Techniques for Electron Microscopy. *James Hillier*, RCA Laboratories, Princeton, N. J. (to be read by *S. C. Ellis*)

Tuesday, October 24

Morning Session

General Survey of Health Physics Instrumentation Problems. *H. M. Parker*, General Electric Company, Hanford Works, Richland, Wash.

Calibration of Radiation Detection Instruments. *L. D. Marinelli*, Argonne National Laboratory

A Calorimetric Method of Measuring High X-Ray Intensities. *Wm. T. Ham, Jr.*, Medical College of Virginia, Richmond, Va.

Consideration of Radiation From High-Voltage Cathode-Ray Tubes. *O. W. Pike*, General Electric Company, Schenectady, N. Y.

Afternoon Session

Fast Neutron Dosimetry and Related Problems. *G. S. Hurst, R. H. Ritchie*, Oak Ridge National Laboratory, Oak Ridge, Tenn.

New Medical Applications of Tracers. *A. H. Holland*, Armour Research Foundation

Electronics and Nucleonics Applied to Enzymes and Viruses. *Ernest C. Pollard*, Yale University

Wednesday, October 25

Morning Session

Manufacture and Quality Control of Geiger Tubes. *D. L. Collins*, Victoreen Instrument Company, Cleveland, Ohio; *D. Atchley*, Tracerlab, Boston, Mass.; and third speaker to be announced

Boron-Lined Neutron Proportional Counters. *W. W. Schultz*, General Electric Company, Schenectady, N. Y.

Design of a Commercial Scintillation Counter. *Edward W. Jervis, Jr.*, W. S. McDonald Company, Cambridge, Mass.

Testing Photomultipliers for Scintillation Counting. *R. W. Engstrom*, RCA Laboratories, Princeton, N. J.

Afternoon Session

Scintillation Counter Instrumentation. *G. Cowper*, Chalk River, Ontario, Canada

Recent Advances in Electron Techniques in Canada. *N. F. Moody*, Chalk River, Ontario, Canada

Fast Counting. *Martin Deutsch*, Massachusetts Institute of Technology, Cambridge, Mass.

New Developments in Mass Spectrometry. *John Hipple*, National Bureau of Standards, Washington D. C.

AIEE Board of Directors Holds Regular Meeting in New York

The regular meeting of the AIEE Board of Directors was held at Institute headquarters, New York, N. Y., August 4, 1950.

Minutes of the meeting of the Board of Directors held June 15, 1950, were approved.

Recommendations adopted by the Board of Examiners at meetings held June 15 and July 20, 1950, were reported and approved. The following actions were taken, as recommended by the Board of Examiners: 28 applicants were transferred and three were elected to the grade of Fellow; 143 applicants were transferred and 86 were elected to the grade of Member; 224 applicants were elected to the grade of Associate; 388 Student members were enrolled.

Expenditures for the months of May and July, amounting to $74,406.60 and $91,871.07 respectively, were reported by the Finance Committee and approved by the Board. A comparison of the income this year up to July 31 with that for the same period last year was reported, which indicated for the present appropriation year a 2-per cent decrease in income.

A proposed transfer guide and transfer publicity pamphlet, prepared by the Committee on Transfers, were submitted and referred back to the committee for further conference with the Board of Examiners and editing, and to the Committee on Planning and Co-ordination for a review of certain basic policies in consultation with the Board of Examiners and the Committee on Transfers.

Upon recommendation of the Committee on Planning and Co-ordination, the Board authorized the holding of the 1952 Fall General Meeting in New Orleans. The Committee on Planning and Co-ordination was empowered to select dates for this meeting and for the Middle Eastern District Meeting to be held in Toledo in the fall of 1952, dates not to be conflicting.

The Committee on Planning and Co-ordination was authorized to work with the Chicago Section of the Institute in arranging AIEE co-operation in the Centennial Celebration of the American Society of Civil Engineers to be held in Chicago in September 1952, and Mr. Frank V. Smith, of Chicago, was appointed the AIEE representative on the ASCE Centennial Committee.

President LeClair reported that, as president of the Institute, he had been selected as a member of the Board of Directors of the 1952 Engineering Centennial Exposition. Upon invitation, the President was empowered to appoint AIEE representatives on an exhibit committee for a permanent exhibit from engineering societies in the Chicago Museum of Science and Industry, such exhibit to be used as a part of the Centennial Exposition.

STANDARDIZING BODIES

The Standards Committee reported appointment of the following AIEE representatives on standardizing bodies:

Sectional Committee C61, Electric and Magnetic Magnitudes and Units: Professor E. Bennett, Chairman, AIEE delegation; R. Rudenberg, W. I. Slichter, I. M. Stein, representatives.

Sectional Committee A85, Protective Lighting for Industrial Properties: D. W. Rowten, representative.

Sectional Committee C40, Storage Batteries: G. W. Vinal, Chairman, sectional committee; J. A. Adams, H. N. Stover, representatives.

Sectional Committee C57, Transformers: D. L. Levine, D. M. MacGregor, representatives.

Sectional Committee C62, Lightning Arresters: G. K. Didlow, representative.

Sectional Committee C7, Bare Electrical Conductors: J. H. Foote, representative.

Sectional Committee C34, Mercury Arc Rectifiers: L. W. Morton, Chairman, sectional committee.

Sectional Committee C55, Capacitors: F. V. Smith, Chairman of newly formed *C55*.

Electrical Section, National Fire Protection Association: W. B. Kouwenhoven, Robin Beach, representatives.

ASA Mining Standardization Correlating Committee: A. C. Muir, representative.

The Standards Committee also reported approval of the following Standards:

Recommended Practice for Testing Insulation Resistance of Rotating Machinery, *Number 43*.

Proposed Standard for Air Switches, Insulator Units and Bus Supports, *Number 28A*.

Proposed Revision of American Standard Abbreviations for Use on Drawings, *Z32.13*.

Proposed Revision of American Standard Guide for Loading Oil-Immersed Step-Voltage and Induction-Voltage Regulators, *C57.35*.

The committee further reported relinquishment by AIEE of sponsorship of Sectional Committee C11, Aluminum Conductors, in order to allow for the consolidation of C11 and H4, Copper Conductors, into a new project, C7, Bare Electrical Conductors, which will include in its scope all bare conductors regardless of the metal they are made of.

A request of Chairman G. T. Minasian of the Committee on Public Relations for provision for continued activity of the committee during the coming year was referred to the Finance Committee for consideration in connection with the preparation of a budget for the year beginning October 1, 1950. The request was accompanied by a report by the retiring chairman, R. K. Honaman, in which he reviewed the work of the committee, expressed his conviction of its importance, and urged the committee's continuance.

The Board voted to adopt a "Statement of Principles of Professional Conduct" recommended by the Committee on Code of Principles of Professional Conduct to replace the existing "Code of Principles of Professional Conduct" adopted in 1912, which the committee had revised to include the "Canons of Ethics for Engineers" previously recommended by the Engineers' Council for Professional Development for adoption by the engineering societies and

Managers of Lehigh Valley Section Meet

At the recent reorganization meeting of the AIEE Lehigh Valley (Pa.) Section in Hazleton, Pa., incoming Chairman George M. Keenan met with the new members of the Board of Managers to discuss plans for the 1950-51 season. Left to right, seated, are: D. L. Greene, D. A. Campbell, Jr., Chairman Keenan, C. H. Sprague (retiring chairman), J. O. Leslie, A. L. Price. Second row, left to right: S. D. Henry, A. W. Plonsky, W. B. Morton, F. X. Ratajezak, R. E. Edmunds, F. M. Fuller, S. C. Townsend, H. R. Wilbur, W. C. Seymour. Third row, left to right: W. B. Bertolet, H. H. Angel, W. F. Dunkle, E. W. Taylor. Fourth row, left to right: J. E. Treweek, F. T. Ritter, J. M. Quinn, A. B. Creveling, Jr.

Philadelphia Section Officers for 1950-51

Above are officers, Board of Managers, and committee chairmen of the AIEE Philadelphia Section for 1950-51. Front row, left to right: L. R. Gaty, Board of Managers; W. F. Henn, Junior Past Chairman; M. J. A. Dugan, Treasurer; H. H. Sheppard, Vice-Chairman; S. R. Warren, Jr., Chairman; W. F. Denkhaus, Secretary; A. P. Godsho, Senior Past Chairman; S. L. Gibble, Board of Managers. Second row, left to right: G. C. Harness, Board of Managers; F. W. A. Myers, Board of Managers; R. C. Crawford, Board of Managers; C. S. Schifreen, Chairman, Transfers Committee; A. E. Pringle, II, Board of Managers; K. Pinder, Chairman, Legislation Committee; W. O. Mascaro, Chairman, Related Activities Committee; R. T. Ferris, Representative, Publications and Publicity Committee, Engineering and Technical Societies Council; H. U. Davis, Chairman, Communications Group Committee. Third row, left to right: M. Lichstein, Chairman, Publicity Committee; W. E. Scholz, Representative, Philadelphia Technical Service Council; W. G. Amey, Chairman, Fellowship and Attendance Committee; H. A. Dambly, Chairman, Committee on National Officer Candidates; C. T. Pearce, Chairman, Papers and Meetings Committee; W. L. Pitts, Chairman, Discussion Groups Committee; R. R. Wagstaff, Chairman, Membership Committee; B. H. Zacherle, Chairman, Student Activities Committee

---

approved by the AIEE Board of Directors. (The new Statement will be published in *Electrical Engineering* and the Year Book.)

The following actions on committee appointments were taken in accordance with the by-laws of the committees concerned:

Charles LeGeyt Fortescue Fellowship Committee: Confirmed the appointment by the President of Guy Kleis and F. E. Sanford as members of the committee for the term of three years beginning August 1, 1950.

Edison Medal Committee: Confirmed the appointment by the President of J. F. Calvert, B. A. Case, and John Grotzinger for the term of five years beginning August 1, 1950, and the reappointment of J. B. MacNeill as chairman of the committee for the year 1950–1951.

Lamme Medal Committee: Confirmed the appointment by the President of W. J. Barrett, L. L. Bosch, and Walther Richter for the 3-year term beginning August 1, 1950.

The annual appointment of AIEE representatives was made (see list in *Electrical Engineering, September 1950, page 838*).

The following Local Honorary Secretaries of the Institute were appointed for the 2-year term beginning August 1, 1950: V. J. F. Brain for Australia; Francis E. Ingham, Transvaal; S. S. Kumar, Northern India; and M. S. Thacker, Southern India.

The following amendments to the Institute by-laws were adopted, in line with the action of the Board of Directors, at its June meeting, increasing Student dues, effective as of May 1, 1951, and as recommended by the Committee on Student Branches:

Section 53. The first part and last sentence amended to read:

Section 53. The annual Student member dues shall be five dollars, payable in advance, and shall cover the fiscal year of the Institute beginning on May first. The initial dues payment, upon application for enrollment, shall be:

$5.00 if application is filed at Institute headquarters during period February 1 to following July 31;

$2.50 if application is filed at any other time.

The renewal of Student membership shall uniformly require payment of the dues of five dollars for the fiscal year beginning May first.... Student membership shall not in any case extend over a period of more than five years.

Section 54. Amended to read:

Section 54. The annual fee of five dollars paid by each Student member shall be applied as a subscription to Electrical Engineering for the year covered by such payment.

A request from the Institute of Electrical Engineers of Japan for resumption of the former relationship between that society and the AIEE, and for co-operation in its postwar efforts, was received. A special committee was appointed to report recommendations regarding methods of co-operation.

Upon recommendation adopted at a conference of vice-presidents and District secretaries held in June, the Board authorized the regular travel allowance for visits of vice-presidents to Subsections, in addition to Sections and Student Branches, at the discretion of the vice-presidents.

The Board expressed its appreciation of the individual efforts of the members of the Panel on National Water Policy of the Engineers' Joint Council and of the excellent report prepared by the Panel, embodying "A Statement of Desirable Policy with Respect to the Conservation, Development, and Use of the National Water Resources," and submitted to the President's temporary Water Resources Policy Commission.

Activities of the Committee on Professional Training of the Engineers' Council for Professional Development were reported and were approved in general.

Vice-President Veinott outlined a plan tentatively adopted last year in the Middle Eastern District for recognition of Section growth. A special committee to be appointed by the President will study the plan and report recommendations to the Board regarding its possibilities on a national level.

Various other matters were discussed at the meeting.

Present at the meeting were:

President T. G. LeClair, Chicago, Ill. Past Presidents J. F. Fairman, New York, N. Y.; Everett S. Lee, Schenectady, N. Y. Vice-Presidents W. C. DuVall, Boulder, Colo.; A. H. Frampton, St. Catharines, Ontario, Canada; R. A. Hopkins, Los Angeles, Calif.; J. A. McDonald, Salt Lake City, Utah; J. R. North, Jackson, Mich.; C. S. Purnell, New York, N. Y.; W. J. Seeley, Durham, N. C.; J. G. Tarboux, Ithaca, N. Y.; C. G. Veinott, Lima, Ohio. Directors W. J. Barrett, Newark, N. J.; E. W. Davis, Cambridge, Mass.; A. G. Dewars, Minneapolis, Minn.; W. L. Everitt, Urbana, Ill.; C. W. Fick, Cleveland, Ohio; M. D. Hooven, Newark, N. J.; F. O. McMillan, Corvallis, Ore.; A. C. Monteith, Pittsburgh, Pa.; Elgin B. Robertson, Dallas, Tex.; H. J. Scholz, Birmingham, Ala.; Victor Siegfried, Worcester, Mass. Treasurer W. I. Slichter, New York, N. Y. Secretary H. H. Henline, New York, N. Y.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

General Applications Division

Committee on Marine Transportation. (*Oscar A. Wilde, Chairman; Joseph B. Feder, Vice-Chairman; W. N. Zippler, Secretary.*) A 2-day meeting of the committee was held on May 11 and 12 and the various subcommittees submitted reports covering additions and changes to be made to Standard *45*. The Subcommittee on Wires and Cables is particularly active in revising the tables on carrying capacities for marine cable. This is quite a problem and requires much study as marine electric cables are entirely different both in structure and application from those used in commercial practice. AIEE Headquarters had advised that the supply of Standard *45* was practically exhausted and since there therefore is not time to make revisions before printing additional copies, it was decided to reprint the Standard with editorial corrections only. However, the committee is continuing its work in assembling the revisions to Standard *45* for a future reprint.

The Committee on Marine Transportation is working with the American Standards Association Sectional Committee *C-42* on the marine sections of "Definitions of Electrical Terms" while a special subcommittee is doing considerable work with the United States National Committee of the International Electrotechnical Commission on electrical marine standardization (the particular assignment is on electric propulsion). The History Subcommittee is working on a history of the Committee on Marine Transportation and the history of electric equipment on shipboard to date.

Industry Division

Committee on Chemical, Electrochemical, and Electrothermal Applications. (*Leroy W. Roush, Chairman; M. A. Hyde, Jr., Secretary.*) The Cathodic Protection Subcommittee of this committee is continuing the work on cathodic protection which was initiated at the Pasadena meeting with papers on the theory and application of the subject. (See Fall General Meeting program, pages 928–29 for the date this session will be held.) There also will be a committee meeting at this time. The Chemical Industry Subcommittee will recommend a session at the Winter General Meeting on "The Installation of Electric Cables in Chemical Plants." This is a continuation of the work on the application of suitable cable installations used in chemical plants, on which subject former conference sessions have been held. The Petroleum Refining and Protection Subcommittee is working on subjects which will be of particular interest to the Canadian petroleum industry and plans to arrange for the presentation of papers at the Summer General Meeting in Toronto next June. A general meeting of the full committee will be held during the New York meeting.

Committee on Electric Welding. (*Myron Zucker, Chairman; R. C. McMaster, Vice-Chairman; C. N. Clark, Secretary.*) The Committee on Electric Welding has received a suggestion from the American Welding Society that, coincident with the AWS proposal to encourage young engineers to become welding engineers, there may be a similar need among electrical engineers to develop electric welding engineers by encouraging welding studies. This matter is being referred to the AIEE Committee on Education. The definition of a "welding engineer," as submitted by the AWS, has been distributed to interested parties to obtain their comments regarding qualifications for such a position.

The Committee on Electric Welding considered various locations for holding the 1952 Welding Conference and it was decided to hold this conference in Detroit in April of that year. As usual, the American Welding Society will be invited to co-operate and the Michigan Sections of both societies will act as hosts.

Power Division

Working Group on Audible Noise in Transformers of Committee on Transformers. (*J. H. Chiles, Jr., Chairman.*) This working group has been working actively on the problem of audible noise in transformers; it is investigating test equipment, test methods, and procedures. In addition, it is reviewing related data and technical information to determine the information already available. The group is investigating also the question of two levels of noise: one for transformers used in residential areas, and a second, and presumably higher, level for transformers used in industrial areas or around power plants. Several papers were presented at the past Winter General Meeting and additional papers will be presented at future meetings. It is proposed to correlate the data on which these papers are based.

Working Group on Substation Grounding Practice of Committee on Substations. (*H. F. Gidlund, Chairman.*) Approximately 130 questionnaires on "Substation Grounding Practice" were mailed out by this working group to a selected list of electrical utilities and to all members of the Substations Committee. Extra questionnaires also were sent to AIEE personnel who are acting in a liaison capacity with the National Association of Corrosion Engineers and the Edison Electric Institute. There were 38 questionnaires returned by June 1 with information requested. Tabulation of the returns will be made and first circulated among the working group members for their preliminary comments before presenting formally the results to the Substations Committee.

Science and Electronics Division

Committee on Electronics. (*W. G. Dow, Chairman; J. T. Thwaites, Vice-Chairman (East); A. M. Zarem, Vice-Chairman (West); E. M. Boone, Secretary.*) The Electronics Committee is considering changes in its organization and structure. Such questions as the following are to be considered in this connection: Is the Electronics Committee too big? Should the committee be broken into two separate committees, one on electron devices, the other dealing with general electronic matters not specifically covered elsewhere, including, for example, passive electronic components, electronic systems engineering, electrostatic processing, and so forth? And to what extent should the official scope of the Electronics Committee be rephrased?

Committee on Basic Sciences. (*M. G. Malti, Chairman; Dimiter Ramadanoff, Vice-Chairman; W. C. Johnson, Secretary.*) The AIEE was represented at the International Congress of Mathematicians at Harvard University, August 30 to September 6, 1950, by two members of this committee, Professors M. G. Malti and Murray F. Gardner. The subcommittees have been most active and the Subcommittee on Applied Mathematics has received several problems for solution, which have been referred to various mathematicians and it is hoped they will be the basis of a future conference. The Subcommittee on Energy Sources and the Subcommittee on Magnetics are sponsoring conferences at the Oklahoma City Fall Meeting and the 1951 Winter General Meeting, respectively.

AIEE PERSONALITIES.....

G. W. Vinal (M '19, F '42), Chief of the Electrochemistry Section, National Bureau of Standards, Washington, D. C., has retired after more than 42 years of service to the government. Dr. Vinal was born on December 17, 1882, in Ellington, Conn., and received the degrees of Bachelor of Arts (1906), Master of Arts (1909), and Doctor of Science (1936) from Wesleyan University. He started with the National Bureau of Standards in 1908 as a laboratory assistant and then successively held the positions of assistant physicist, physicist, and chief of the electrochemistry section. He attained the latter position in 1918. Dr. Vinal is internationally known for his research in the field of electrochemistry, particularly for his work in the development and perfection of the silver voltameter and the standard cell, which serve as standards for the international ampere and volt. He has also done extensive research on dry cells and storage batteries. Dr. Vinal has contributed extensively to scientific journals in the fields of electrochemistry and batteries. In recognition of his outstanding work, France awarded him the Gaston Plante Medal of the Societe de Francaise des Electriciens in 1938. He was an exchange physicist to the Physikalisch Technische Reichsanstalt in 1931, and received a Certificate of Commendation from the Navy Bureau of Ships in 1947 and a

G. W. Vinal

Certificate from the Office of Scientific Research and Development in 1946. During World War II, Dr. Vinal carried out an extensive program of research in storage batteries and dry-cell development for the United States Navy and, in addition, served as the chairman of the Joint Army and Navy Committee on Battery Research, which directed the whole military development program on batteries for the Armed Forces. Dr. Vinal served the Institute as a member of the following committees: Chemical, Electrochemical, and Electrothermal Applications (1922–23, Chairman 1924–29, 1930–34, 1948–50); Meetings and Papers (1924–29); and Standards (1924–27). He is also chairman of the Technical Committee on Batteries, Federal Security Board, the American Standards Association Committee on Dry Cells, and technical advisor of the United States National Committee of the International Electrochemical Commission. Dr. Vinal is a member of the National Research Council, The American Association for the Advancement of Science, the American Chemical Society, the Washington Academy of Science, and Phi Beta Kappa.

L. C. F. Horle (A '20, F '35), Chief Engineer of the Engineering Department and Manager of the Data Bureau, Radio-Television Manufacturers Association, New York, N. Y., has retired. Mr. Horle had been with the association for 15 years. Mr. Horle was born in Newark, N. J., on May 27, 1892, and was educated at Stevens Institute of Technology. From 1914 to 1916 he was an instructor in the physics department at Stevens and, in 1916, he became associated with the Public Service Corporation of New Jersey as a designer of special industrial equipment. From 1917 to 1920 Mr. Horle was Civilian Chief of the Radio Laboratory, Navy Yard, Washington, D. C., and, in 1920, became chief engineer for the Deforest Radio Telephone and Telegraph Company. He spent the years 1921 through 1924 as a consulting engineer and simultaneously as a member of the consulting staff of the Department of Commerce, Radio Laboratory, Bureau of Standards. In 1924, Mr. Horle became chief engineer of the Federal Telephone and Telegraph Company and vice-president of the Federal Telephone Manufacturing Corporation, Buffalo, N. Y. In 1929 he became a consulting engineer on design and construction of radio transmitting systems. Mr. Horle served the Institute as a member of the Committee on Electronics from 1945 to 1947. He is a past president of the Radio Club of America and is a member of the Institute of Radio Engineers.

G. I. Tour (M '46), electrical engineer, Tennessee Valley Authority, has retired. Mr. Tour was born in Elisavetgrad, Russia, on July 25, 1880, and was graduated from the University of Nancy (France) in 1907 with an electrical engineering degree. After a brief period of testing electric machinery with Societe Gramm, Paris, France, he designed and supervised electric installations in 1908 for Tournie, Martine, and Company in Paris. From 1909 to 1910 he was employed by Wostok Company, Odessa, Russia, as engineer in charge of its technical division. In 1910, he joined the Auer Company of Odessa, where he designed and supervised electric installation until 1915, when he came to the United States and obtained employment as an electrical estimator and journeyman-electrician for small electrical contractors. From 1916 to 1917 he worked as a tester and designer of electric machinery for Bogue Electric Company, New York, N. Y. During 1917, he accepted a position with Stone and Webster, Boston, Mass., where he was employed as an electrical draftsman, designer, checker, and squad chief. Mr. Tour was also employed in the Electrical Engineering Department of the Boston Navy Yard. He joined the Electrical Design Branch of the Tennessee Valley Authority in 1936 and remained with the agency until his retirement.

R. V. Sprague (M '45), Regional Power Manager, United States Bureau of Reclamation, Boulder City, Nev., has retired. Mr. Sprague was born in Wadena, Minn., on June 6, 1880, and furthered his education with the International Correspondence School and the Alexander Hamilton Institute. Before joining the Bureau of Reclamation, Mr. Sprague worked for the Los Angeles (Calif.) Gas and Electric Company as an electrical engineer and superintendent on the installation of steam and electric equipment and also in the same capacity on electric subways in Buenos Aires, Argentina. He joined the Bureau of Reclamation in 1935 and was assigned to installation of equipment at the powerhouse and switchyards at Boulder Dam. In 1944, he was transferred to regional offices to take charge of the branch of power utilization.

H. H. Rudd (A '18, M '46), Vice-President and Consulting Engineer, Railway and Industrial Engineering Company (a subsidiary of I-T-E Circuit Breaker Company), Greensburg, Pa., has retired, but will continue to serve the company as an engineering consultant. Mr. Rudd was born in Kewanee, Ill., on June 7, 1880, and received the degrees of Bachelor of Arts and Master of Arts from Trinity College. He also did graduate work at Rensselaer Polytechnic Institute. From 1906 to 1919, Mr. Rudd was manager of power transformer sales for the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), East Pittsburgh, Pa. In 1919, Mr. Rudd became Vice-President of the Railway and Industrial Engineering Company. He is serving the Institute as a member of the Switchgear Committee, of which he has been a member since 1947. Mr. Rudd was also a member of the Protective Devices Committee from 1941 to 1943 and from 1944 to 1947.

W. C. Johnson (A '35, M '42), Professor of Electrical Engineering, Princeton University, Princeton, N. J., has been appointed chairman of the department of electrical engineering at the university. He will succeed **C. H. Willis** (A '22, F '42), who has been chairman since 1936. Dr. Willis will continue in the department and also work on the text of a book he has in preparation. Dr. Willis has been a member of the Princeton faculty since 1926 and previous to that time taught at the University of Richmond. He received the degree of Bachelor of Science from the University of Richmond in 1914. He also received the degrees of Bachelor of Science in engineering and Doctor of Philosophy from The Johns Hopkins University. During World War I, he was an instructor at the United States Army Signal School at Langres, France. Professor Johnson has been engaged for several years in research work on magnetic amplifiers and has had papers published on his work in that field. He is also the author of a book, "Mathematical and Physical Problems of Engineering Analysis." Professor Johnson received a Bachelor of Science degree in engineering from Pennsylvania State College in 1934 and the degree of Electrical Engineer from the same college in 1940. Before joining the faculty at Princeton, he was with the General Electric Company. Dr. Willis has served the Institute as Chairman of the Technical Program Committee since 1949 and is, at present, also a member of the following committees: Standards, Publications, Planning and Co-ordination, Public Relations, Electronic Power Converters, and Electronics.

J. D. Wright (A '36, M '43), Manager, Industrial Engineering Divisions, General Electric Company, has been appointed assistant manager of the company's Industry Divisions. **F. M. Roberts** (M '42, F '48), Assistant Manager, Industrial Engineering Divisions, will replace Mr. Wright as manager. **L. A. Umansky** (A '16, F '45), Industrial Engineering Divisions, will assume the post of manager of engineering, of the Industrial Engineering Divisions. Mr. Roberts is serving the Institute as a member of the Management Committee and Mr. Umansky as a member of the Committee on Award of Prizes, Lamme Medal, and General Industry Applications Committees.

C. S. Allen (A '31, M '37), Vice-President and General Manager, Pacific Coast Division, A. O. Smith Corporation, Milwaukee, Wis., has been elected executive vice-president and general manager of the Russell Electric Company Division of the Raytheon Manufacturing Company in Chicago, Ill. Prior to his association with the A. O. Smith Corporation, Mr. Allen had been with the General Electric Company for 16 years. During World War II, he was section engineering in General Electric's fractional-horsepower motor engineering division in Fort Wayne, Ind. He was in charge of all engineering on a-c motors for this division.

A. D. Steele (A '46), Field Engineer, Minnesota Mining and Manufacturing Company, Cleveland, Ohio, has been named sales supervisor for electric and sound recording tapes in the St. Paul, Minn., area. Mr. Steele has been with the company since 1945.

H. A. Hart (A '48), Electrical Engineer, Electrical Engineering Department, Armour Research Foundation, Chicago, Ill., heads an organization known as Henry A. Hart and Associates, which has opened a laboratory devoted to product development and commercial testing of all types of electrical equipment and materials at 23 West Hubbard Street, Chicago, Ill. The new laboratories are designed to conduct tests on materials and devices used in the generation, distribution, transformation, and consumption of electricity. Also available is a consulting service designed to augment the engineering staff of industrial concerns.

R. A. Sovik (A '40, M '43), Engineer, Copperweld Steel Company, Glassport, Pa., has been elected President of the New York State Society of Professional Engineers. Mr. Sovik is a member of the Central New York Chapter of the Society at Syracuse, N. Y., and has been on the state executive committee for the past six years. He served as zone director for two terms and as state first vice-president last year. He is a past state chairman of membership and educational committees and a director of the national Society.

A. G. Conrad (A '27, F '49), Head of the Department of Electrical Engineering, Yale University, New Haven, Conn., has been elected Vice-President of the Engineering College Research Council. Mr. Conrad is serving the Institute as Chairman of the Charles LeGeyt Fortescue Fellowship Committee, and as a member of the Research Committee.

E. M. Strong (A '26, M '40), Professor of Electrical Engineering, Cornell University, Ithaca, N. Y., has been elected Vice-President of the Illuminating Engineering Society, New York, N. Y. Mr. Strong is a member of the AIEE Committees on Education and Production and Application of Light. **A. H. Manwaring** (A '40, M '46). Vice-President, Philadelphia (Pa.) Electrical and Manufacturing Company, has been elected General Secretary of the society.

George Skipton (A '36), application engineer, transportation division, Westinghouse Electric Corporation, San Francisco, Calif., has been placed in charge of all the company's activities having to do with the supplying of electrical apparatus to the city and county of San Francisco. Mr. Skipton has been with Westinghouse since 1913 and has been located in San Francisco since 1922.

A. D. Hinckley (A '27, M '38), Executive Secretary, Illuminating Engineering Society, New York, N. Y., has been elected the twenty-ninth president of the Columbia University Engineering School Alumni Association. Mr. Hinckley was assistant to the dean of the Faculty of Engineering of Columbia University from 1935 to 1944. In 1944 he became a member of the Illuminating Engineering Society.

M. M. York (A '43), Sales Representative, Allis-Chalmers Manufacturing Company, Charlotte, N. C., has been named manager of the company's Boston, Mass., district office. Mr. York joined Allis-Chalmers in 1939 following his graduation as an electrical engineer from North Carolina State College. He was assigned to the Charlotte office in 1941.

L. G. Cover (A '20, M '40), Assistant Manager, Cleveland (Ohio) Wire Works, General Electric Company, has become manager of the wire works. Mr. Cover has just completed 40 years with the Lamp Department of General Electric, most of them in the employ of the Cleveland Wire Works. He attended Iowa State College, where he received the degree of Bachelor of Science in electrical engineering.

E. P. Nelson (A '27, M '45), Consulting Electrical Engineer, Mount Vernon, N. Y., has been named a vice-president of Designers for Industry, Inc., of Cleveland, Ohio, and will represent the company in northern New Jersey, metropolitan New York including Long Island, Connecticut, and Rhode Island. Mr. Nelson will continue his consulting work for certain clients.

F. L. Headley (A '29, M '45), Manager, Apparatus Department, General Electric Company, Philadelphia, Pa., has been appointed assistant manager of the Pittsburgh, Pa., Apparatus Sales Office. Mr. Headley will replace Joseph Bryan, the present manager, upon his retirement. Mr. Headley has been with General Electric since 1923.

J. J. Greagan, Jr. (A '46), Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been assigned to the company's Charlotte, N. C., district office as a sales representative. Mr. Greagan is an electrical engineering graduate of Alabama Polytechnic Institute and has been with Allis-Chalmers since 1948.

H. J. McCreary (A '24, F '46), Consulting Engineer, Automatic Electric Company, Chicago, Ill., was awarded the professional degree of Electrical Engineer by the University of Nebraska on June 5, 1950. Mr. McCreary received the degree of Bachelor of Science in Electrical Engineering from the University of Nebraska in 1923.

Sydney Alling (A '12, M '18, Member for Life), Manager, Industrial and Commercial Sales, Rochester (N. Y.) Gas and Electric Corporation, has been named general sales manager. Mr. Alling is a graduate of the University of Rochester and Massachusetts Institute of Technology and has been with the company for 39 years.

P. F. Manieri (A '47), Assistant to General Manager, International Business Machines Corporation, Endicott, N. Y., has been appointed assistant to the vice-president. Mr. Manieri has been with International Business Machines Corporation since 1938.

A. C. Northover (A '49), Municipal Engineer, Midland (Ontario, Canada) Public Utilities, has been appointed resident engineer for McKim Township, Sudbury, Ontario, Canada. Mr. Northover has served as the Municipal Engineer of Midland since 1947.

F. S. Jones, Sr. (A '14, M '41, Member for Life), Staff Engineer, Lubricating Oil Department, Socony Vacuum Oil Company, Inc., New York, N. Y., received the degree of Mechanical Engineer from the University of Maine on June 18, 1950.

H. H. Brown (A '26, M '36), Chief Electrical Engineer, Wisconsin Michigan Power Company, Appleton, Wis., was cited recently by the University of Wisconsin for his outstanding accomplishments in engineering and industrial fields.

C. M. Montplaisir (A '49), Wired-Radio Sales Engineer, Line Material Company, East Stroudsburg, Pa., has been appointed assistant to the Eastern Division Sales Manager. Mr. Montplaisir joined the company in 1948 as a sales engineer.

R. M. Smith (A '35, M '46), Manager, Distribution Engineering, Railway and Industrial Engineering Company, Greensburg, Pa., has been appointed chief engineer. Mr. Smith has been with the company since 1945.

D. M. Quick (A '43, M '45), Senior Engineer, Public Service Electric and Gas Company, Newark, N. J., has been appointed Assistant to the Chief Engineer, Electric Engineering Department. Mr. Quick was graduated from Lehigh University in 1923 with a mechanical engineering degree and started with the Public Service Electric and Gas Company that same year. He was promoted to the position of senior engineer in 1948.

W. A. Furst (A '13, M '27, Member for Life), District Manager, Gould Storage Battery Company, Pittsburgh, Pa., has been appointed Director of Public Utilities, City of Gainesville, Fla. Mr. Furst was at one time associated with the Westinghouse Electric Corporation. He was Chairman of the Pittsburgh Section of AIEE from 1938 to 1939 and Secretary of the Section from 1937 to 1938.

M. I. Alimansky (A '45, M '50), Assistant Manager of Engineering, Transformer and Allied Products Divisions, General Electric Company, Pittsfield, Mass., has been appointed assistant manager of manufacturing for the divisions.

J. W. Eakins (A '47), Jesse W. Eakins Company, Detroit, Mich., has been appointed the eastern Michigan and the Toledo, Ohio, metropolitan area sales representative of Centric Clutch Company, Cranford, N. J.

E. H. Ulm (A '46), Sales Engineer, Electronics Division, Sylvania Electric Products Inc., New York, N. Y., has been appointed merchandising manager. Mr. Ulm is a member of the Institute of Radio Engineers and the Radio Club of America.

T. O. Moloney, Jr. (A '39, M '48), Treasurer, Moloney Electric Company, St. Louis, Mo., has been elected Chairman of the Board of the company.

OBITUARY • • • • • •

Nicholas Mikhailovich Oboukhoff (M'24, F '38), Research Professor Emeritus of Electrical Engineering and Professor Emeritus of Mathematical Physics, Oklahoma Agricultural and Mechanical College, Stillwater, died July 30, 1950. Dr. Oboukhoff was born in Novocherkassk, Russia, on July 8, 1873, and received the following degrees: University Diploma in Physics and Mathematics, University of Moscow (Russia), 1895; mechanical engineer, Imperial Institute of Technological Science of Kharkov (Russia), 1904; Ingenieur Electricien Diplome, École Superieure d'Electricité de Paris (France), 1909; and Doctor of Philosophy cum laude, California Institute of Technology, Pasadena, 1929. Dr. Oboukhoff's industrial experience was gained in many foreign countries including France, Switzerland, England, Belgium, Italy, Austria, Germany, Egypt, Palestine, and Russia. From 1918 to 1919 he was Commissioner of Labor in the Donetz District and Ural District, Russia, under the Provisional Government. He was also in charge of the Irkut River Project, which was concerned with hydroelectric development of the Irkut River, in Irkutsk, Russia. Dr. Oboukhoff's teaching experience was also gained in many parts of the world. He was an instructor and later assistant professor of physics and electrical engineering at the University of Irkutsk and the Institute of Technological Science, Tomsk, Russia from 1920 to 1921; professor of theoretical mechanics, hydraulics, and electrical engineering at the Polytechnic Institute of Harbin (China), from 1921 to 1930. He was commissioned to the United States for research work from 1927 to 1930 by the same institute and, from 1922 to 1930, he was dean of the department of mechanical and electrical engineering, head of the laboratory of electrical engineering and electrophysics, editor of *Transactions* and *Journal of Polytechnic Institute of Harbin*, at that institute. Dr. Oboukhoff became associate professor of electrical engineering at Oklahoma Agricultural and Mechanical College in 1929 and was made a full research professor of electrical engineering at the same college in 1930. He became, in addition, professor of mathematical physics at the college in 1936. Dr. Oboukhoff was the holder of patents in France, the United States, and England which dealt chiefly with medium- and high-frequency alternators. He had many technical papers published in scientific and engineering magazines of France, Russia, China, Germany, and the United States. He was a member of the Association of University Professors, Sigma Xi, Eta Kappa Nu, and the Institute of Radio Engineers. He was also a fellow of the American Association for the Advancement of Science and the Oklahoma Academy of Science.

John Eugene Allen (A '21, M '39, F '47), Chief of Tests, Pennsylvania Water and Power Company and the Safe Harbor Water Power Corporation, Baltimore, Md., died August 6, 1950. Mr. Allen was born near Carlisle, Pa., on November 18, 1892, and received the degree of Bachelor of Science in electrical engineering from Pennsylvania State College in 1916. Mr. Allen had been employed by the Pennsylvania Water and Power Company since 1918 and was appointed Chief of Tests in 1923. In 1931, he became chief of tests for the Safe Harbor Water Power Corporation as well. Mr. Allen was known for his work in developing the high-frequency fault locator and, in 1935, he received a first prize award by the Edison Electric Institute for this work. Another of his inventions was a high-speed frequency indicating meter which permitted instantaneous perception of a-c frequency. Other of his research accomplishments contributed to the reduction of the effects of lightning on transmission lines, the improvement of governors for hydro turbines, the measurement of radio field strength preliminary to the design of a space radio system, and the design and construction of equipment for carrier current and land wire telephone systems. Mr. Allen had actively served the Institute as a member of the following committees: Power Generation (1949–50); Rotating Machinery (1947–50); Communication (1939–41); and Protective Devices (1929–31). He was also a liaison representative of the Power Generation Committee of the Subcommittee on Hydraulic Turbine Speed Specifications of AIEE-ASME (The American Society of Mechanical Engineers). Mr. Allen was also a member of the National Association of Corrosion Engineers, the Instrument Society of America, the American Association for the Advancement of Science, and the Institute of Radio Engineers.

Alzamora Burdette Smith (A '40), Assistant Manager, Engineering Department, National Electrical Manufacturers Association, New York, N. Y., died August 15, 1950. Mr. Smith was born on February 15, 1895, in New York, N. Y., and was graduated from Yale University in 1916 with the degree of Bachelor of Philosophy in electrical engineering. From 1916 to 1918, Mr. Smith was with the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) and from 1918 to 1921 he served in the Submarine Service of the United States Navy. Mr. Smith joined the United Electric and Power Company (now Consolidated Edison) for one year and then became associated with Underwriters' Laboratories, Inc., as assistant electrical engineer from 1923 to 1930. He had been with the National Electrical Manufacturers Association since 1930. Mr. Smith served the Institute as a member of the Safety Committee from 1945 to 1950.

Stephen I. Balogh (A '44), professional electrical engineer, Seattle, Wash., died July 31, 1950. Mr. Balogh was born in Budapest, Hungary, on March 6, 1874, and received the degrees of Mechanical Engineer and Electrical Engineer from the Royal Joseph University of Technology in Budapest in 1897. Mr. Balogh's industrial career was spent both in the United States and Hungary. In Hungary, he worked for various public utilities and, at one time, was head of the electric design department of Seimens Halske, a large European electrical corporation. In the United States, Mr. Balogh was associated with many electrical concerns as a design engineer, including Crystal and Crystal, New York, N. Y.; Wappler Electric Company, Long Island City, N. Y.; and the American Gas and Electric Company, New York, N. Y. Mr. Balogh was a member of The American Society of Mechanical Engineers and the National Society of Professional Engineers.

John Selby Parsons (A '27, M '47), Distribution Engineer, Industry Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., died August 22, 1950. Mr. Parsons was born in Accomac, Va., on June 15, 1899, and was educated at the United States Naval Academy and Georgia School of Technology and received the degree of Bachelor of Science in mechanical engineering in 1921 from the latter school. Mr. Parsons had been continuously associated with the Westinghouse Electric Corporation since 1922 and among his developments for the company were: the first Westinghouse network relay, the first 3-phase network relay, and the first secondary network system for industrial plant use and also for electric power distribution on large ships. He held over 40 patents on relays, electric distribution systems, and associated equipment. He was also the author of many technical papers which have been published in scientific journals.

MEMBERSHIP • • • •

Recommended for Transfer

As there was no meeting of the Board of Examiners during the month of August, there is no transfer posting list this month.

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before October 25, 1950, or December 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Bishop, G. S., Bell Tel. Labs., New York, N. Y.
Briggs, R. E., Mallett & Assocs., Jackson, Miss.
Burke, E. F., c/o E. F. Burke Agency, Cleveland, Ohio
Burkett, A., Bell Tel. Labs., New York, N. Y.
Coffman, P. R., Coffman Elec. Co., Grand Rapids, Mich.
Cosgriff, R. L., Curtiss-Wright Corp., Columbus, Ohio
Coyle, D. K., c/o OINCC, Station 10, Guam, Guam
Epperson, J. B., Howard Radio & Television Station, Inc. & Television Station WEWS, Cleveland, Ohio
Fickinger, C. H., N. Y. Tel. Co., New York, N. Y.
Hare, W. K., Univ. of Buffalo, Buffalo, N. Y.
Hatfield, B. F., Southern Bell Tel. & Tel. Co., New Orleans, La.
Hubert, E. H. A., Union des Centrales Electriques de Liege-Namur-Luxembourg, Liege, Belgium
Hughes, Y. L., Sr., Gulf States Utilities Co., Beaumont, Tex.
Kenline, F. J., Lake Erie Engg. Corp., Kenmore, N. Y.
Margoulies, S., Union des Centrales Electriques de Liege-Namur-Luxembourg, Liege, Belgium
Moxon, H. W., Canadian General Elec. Co., Ltd., Montreal, Quebec, Canada
Orr, R. L., Natl. Advisory Comm. for Aeronautics, Langley Air Force Base, Va.
Parsons, F. M., Kellogg Switchboard & Supply Co., Chicago, Ill.
Pennypacker, R. M., Philadelphia Elec. Co., Philadelphia, Pa.
Perez, C. P., "Don. Gral. de Fabricaciones Militares," Buenos Aires, Argentina, So. Amer.
Smith, K. C., Gouverneur Talc. Co., Gouverneur, N. Y.
Snyder, R. L., Jr., Ballistic Research Labs., Aberdeen Proving Ground, Md.
Stancliff, G. L., Jr., Vickers Elec. Div., St. Louis, Mo.
Thym, G. C., Joy Mfg. Co., St. Louis, Mo.
Welch, J. E., Western Massachusetts Elec. Co., Springfield, Mass.
Whitman, R. L., 17 S. W. 13th St., Miami, Fla.
Yeow, N. K., Perak River Hydro Elec. Power Co., Ltd., Ipoh, Malaya

27 to grade of Member

AIEE Technical Subcommittees—1950–51

Communication Division

Communication Switching Systems

No subcommittees

Radio Communications Systems

Mobile Radio Subcommittee

A. C. Dickieson, *Chairman;* Bell Telephone Laboratories, Inc., 463 West Street, New York 14, N. Y.
C. M. Backer, Clifton, N. J.
I. F. Byrnes, New York, N. Y.
G. E. Dodrill, Washington, D. C.
J. W. Kearney, Mineola, N. Y.
L. P. Morris, Chicago, Ill.
David Talley, New York, N. Y.

Point-to-Point Radio Subcommittee

E. D. Becken, *Chairman;* R.C.A. Communications, Inc., 66 Broad Street, New York 4, N. Y.
R. D. Campbell, New York, N. Y.
H. P. Corwith, New York, N. Y.
Edward Daskam, Jr., New York, N. Y.
G. E. Dodrill, Washington, D. C.
L. W. Gregory, Baltimore, Md.
D. D. Grieg, Nutley, N. J.
S. C. Leyland, Newark, N. J.

Special Communications Applications

Electro-Acoustics Subcommittee

R. B. Vaile, Jr., *Chairman;* Standard University, Stanford Research Institute, Stanford, Calif.
I. F. Byrnes, New York, N. Y.
L. C. Holmes, Rochester, N. Y.
H. H. Spencer, Camden, N. J.

Railroad Communications Subcommittee

W. D. Hailes, *Chairman;* General Railway Signal Company, 801 West Avenue, Rochester 11, N. Y.
G. W. Baughman, Swissvale, Pa.
L. E. Kearney, New York, N. Y.
R. H. Kline, Baltimore, Md.
Newton Monk, New York, N. Y.

Special Activities Subcommittee

A. J. Warner, *Chairman;* Federal Telecommunication Laboratories, 500 Washington Avenue, Nutley 10, N. J.
Melville Eastham, Cambridge, Mass.
R. H. Kline, Baltimore, Md.
Newton Monk, New York, N. Y.
H. H. Spencer, Camden, N. J.

Telegraph Systems

Facsimile Subcommittee

R. E. Mathes, *Chairman;* Gray Research and Development Company, Inc., 16–30 Arbor Street, Hartford 1, Conn.
A. G. Cooley, New York, N. Y.
W. G. H. Finch, Washington, D. C.
J. V. L. Hogan, New York, N. Y.
Grosvenor Hotchkiss, New York, N. Y.
J. R. Krchek, Washington, D. C.

Television and Aural Broadcasting Systems

No subcommittees

Wire Communications Systems

No subcommittees

General Applications Division

Air Transportation

Aircraft Electrical Rotating Machinery Subcommittee

L. R. Larson, *Chairman;* Naval Research Laboratory, Washington, D. C.
J. W. Allen, Teterboro, N. J.
J. B. Crockford, Lima, Ohio
William Fell, Cleveland, Ohio
S. H. Hanville, Jr., Washington, D. C.
R. D. Jones, Fort Wayne, Ind.
Paul Lebenbaum, Jr., Lynn, Mass.
G. W. Sherman, Dayton, Ohio
R. R. Smith, Baltimore, Md.

Aircraft Electrical Systems Subcommittee

G. W. Almassy, *Chairman;* General Electric Company, 6900 South Stanford Avenue, Los Angeles 1, Calif.
J. W. Allen, Teterboro, N. J.
Phil. Binderman, Washington, D. C.
H. B. Bunce, East Pittsburgh, Pa.
L. M. Cobb, Johnsville, Pa.
D. W. Exner, Seattle, Wash.
H. L. Hildebrandt, Dayton, Ohio
C. S. Milliken, Burbank, Calif.
W. F. Moore, Schenectady, N. Y.
G. A. Phillips, Schenectady, N. Y.
V. O. Ray, Los Angeles, Calif.
D. H. Scott, Washington, D. C.
A. J. Snyder, Tulsa, Okla.
A. F. Trumbull, Santa Monica, Calif.

Principles of Altitude Rating of Electrical Apparatus Subcommittee

Karl Martinez, *Chairman;* Boeing Airplane Company, Plant 1, Seattle, Wash.
J. W. Allen, Teterboro, N. J.
S. H. Hanville, Jr., Washington, D. C.
V. C. Holloway, Washington, D. C.
J. G. Hutton, Schenectady, N. Y.
C. A. Maple, Dayton, Ohio
R. A. Rugge, Grand Rapids, Mich.

Aircraft Electrical Control, Protective Devices and Cable Subcommittee

B. O. Austin, *Chairman;* Aviation Engineering Department, Westinghouse Electric Corporation, Lima, Ohio
Earl Barlow, Baltimore, Md.
E. E. Magee, Dayton, Ohio
R. A. Millermaster, Milwaukee, Wis.
H. S. Moore, New Haven, Conn.
W. F. Moore, Schenectady, N. Y.
J. Ottmar, Attleboro, Mass.
Milton Schach, Washington, D. C.
Omar Wally, Cleveland, Ohio
W. W. West, New York, N. Y.

Domestic and Commercial Applications

Electric Heating of Homes and Heat Pumps Subcommittee

J. C. Beckett, *Chairman* (West); Wesix Electric Heater Company, 390 First Street, San Francisco 5, Calif.
T. C. Johnson, *Chairman* (East); General Electric Company, 5 Lawrence Street, Bloomfield, N. J.

Domestic Appliances Subcommittee

C. R. Reid, *Chairman;* Engineering Laboratories, The Hoover Company, North Canton, Ohio

Land Transportation

Heavy Traction Electrification Data Subcommittee

L. W. Birch, *Chairman;* Ohio Brass Company, Mansfield, Ohio
H. F. Brown, New Haven, Conn.
A. G. Oehler, New York, N. Y.
R. A. Williamson, Erie, Pa.
G. M. Woods, East Pittsburgh, Pa.

Projects:

(*1*). Catenary overhead systems
(*2*). Third rail systems
(*3*). Electric locomotives
(*4*). Substations
(*5*). Power supply

The personnel of the projects is as follows: (*1*) and (*2*). L. W. Birch, *Chairman,* Ohio Brass Company, Mansfield, Ohio; H. F. Brown, New Haven, Conn. (*3*), (*4*), and (*5*). A. G. Oehler, New York, N. Y.; R. A. Williamson, Erie, Pa.; G. M. Woods, East Pittsburgh, Pa.

Heavy Traction Papers and Plans Subcommittee

H. F. Brown, *Chairman;* New York, New Haven, and Hartford Railroad, Railroad Station, New Haven, Conn.
W. A. Brecht, East Pittsburgh, Pa.
R. L. Kimball, New York, N. Y.

Light Traction Papers and Plans Subcommittee

G. M. Woods, *Chairman;* Industry Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa.
H. R. Blomquist, Providence, R. I.
D. L. Smith, Highwood, Ill.

Subcommittee on Revision of AIEE Standard Number 16 (Electric Railway Control Apparatus) ASA C48

R. A. Williamson, *Chairman;* Railroad Rolling Stock Division of Locomotive and Car Equipments Divisions, General Electric Company, Erie, Pa.
P. H. Hatch, New Haven, Conn.
J. G. Inglis, Toronto, Ontario, Canada
G. M. Woods, East Pittsburgh, Pa.

Marine Transportation

Power Generation Subcommittee

Clarence Lynn, *Chairman;* Westinghouse Electric Corporation, East Pittsburgh, Pa.
W. B. Armstrong, Washington, D. C.
H. C. Coleman, East Pittsburgh, Pa.
L. M. Goldsmith, Philadelphia, Pa.
W. E. Jacobsen, Schenectady, N. Y.
E. H. Stivender, Milwaukee, Wis.
O. A. Wilde, Chester, Pa.

Power Application Subcommittee

L. M. Goldsmith, *Chairman;* Atlantic Refining Company, 260 South Broad Street, Philadelphia, Pa.
W. B. Armstrong, Washington, D. C.
H. C. Coleman, East Pittsburgh, Pa.
W. E. Jacobsen, Schenectady, N. Y.
J. E. Jones, Milwaukee, Wis.
Clarence Lynn, East Pittsburgh, Pa.
E. H. Stivender, Milwaukee, Wis.

Wires and Cables Subcommittee

W. N. Zippler, *Chairman;* Gibbs and Cox, Inc., 1 Broadway, New York 4, N. Y.
P. J. DuMont, New York, N. Y.
J. B. Feder, Washington, D. C.
A. R. Gatewood, New York, N. Y.
W. E. Jacobsen, Schenectady, N. Y.
V. W. Mayer, Washington, D. C.
W. H. Reed, New York, N. Y.

Switchboards and Control Subcommittee

H. C. Coleman, *Chairman;* Westinghouse Electric Corporation, East Pittsburgh, Pa.
P. J. DuMont, New York, N. Y.
H. F. Harvey, Jr., Newport News, Va.
J. E. Jones, Milwaukee, Wis.
C. Krommenhock, Brooklyn, N. Y.
J. D. Shuster, Quincy, Mass.
E. H. Stivender, Milwaukee, Wis.

Distribution Subcommittee

H. F. Harvey, Jr., *Chairman;* Newport News Shipbuilding and Dry Dock Company, Newport News, Va.
W. B. Armstrong, Washington, D. C.
A. R. Gatewood, New York, N. Y.
E. A. Geary, Camden, N. J.
L. M. Goldsmith, Philadelphia, Pa.
P. A. Guise, New York, N. Y.
V. W. Mayer, Washington, D. C.
W. N. Zippler, New York, N. Y.

Fittings and Appliances Subcommittee

V. W. Mayer, *Chairman;* United States Maritime Commission, Technical Division, United States Department of Commerce Building, Washington, D. C.
P. J. DuMont, New York, N. Y.
J. B. Feder, Washington, D. C.
R. W. Frost, Amesbury, Mass.
E. A. Geary, Camden, N. J.
P. A. Guise, New York, N. Y.
H. F. Harvey, Jr., Newport News, Va.
E. M. Rothen, New York, N. Y.
J. D. Shuster, Quincy, Mass.
O. A. Wilde, Chester, Pa.

Communications and Alarm Subcommittee

W. H. Reed, *Chairman;* Bruce Electric Company, 196 West Houston Street, New York 14, N. Y.
R. W. Frost, Amesbury, Mass.
A. R. Gatewood, New York, N. Y.
E. A. Geary, Camden, N. J.
C. Krommenhock, Brooklyn, N. Y.
S. N. Mead, Amesbury, Mass.
E. M. Rothen, New York, N. Y.
J. D. Shuster, Quincy, Mass.
C. W. Souder, Great Neck, N. Y.

Navigation Equipment Subcommittee

S. N. Mead, *Chairman;* Sig-Trans, Inc., Haverhill Road, Amesbury, Mass.
R. W. Frost, Amesbury, Mass.
P. A. Guise, New York, N. Y.
C. Krommenhock, Brooklyn, N. Y.
E. M. Rothen, New York, N. Y.
G. W. Souder, Great Neck, N. Y.

Publicity, Personnel, and History Subcommittee

W. H. Reed, *Chairman;* Bruce Electric Company, 196 West Houston Street, New York 14, N. Y.
H. F. Harvey, Jr., Newport News, Va.

Editing Subcommittee

W. N. Zippler, *Chairman;* Gibbs and Cox, Inc., 1 Broadway, New York 4, N. Y.
J. B. Feder, Washington, D. C.
H. F. Harvey, Jr., Newport News, Va.
W. H. Reed, New York, N. Y.

International Standardization Subcommittee

A. R. Gatewood, *Chairman;* American Bureau of Shipping, 45 Broad Street, New York 4, N. Y.
H. C. Coleman, East Pittsburgh, Pa.
H. F. Harvey, Jr., Newport News, Va.
W. N. Zippler, New York, N. Y.

Production and Application of Light

Nomenclature of Electronic Lamps Subcommittee

R. C. Putnam, *Chairman;* Case Institute of Technology, Cleveland, Ohio
G. S. Evans, Bloomfield, N. J.
L. R. Keiffer, Cleveland, Ohio
T. C. Sargent, Salem, Mass.

Industry Division

Chemical, Electrochemical and Electrothermal Applications

Arc Furnaces and Electrothermal Processes Subcommittee

E. H. Browning, Jr., *Chairman;* Industry Engineering Department 10-L, Westinghouse Electric Corporation, East Pittsburgh, Pa.
F. V. Andreae, Chattanooga, Tenn.
W. L. Bundy, Wilson Dam, Ala.
R. A. Geiselman, East Pittsburgh, Pa.
E. A. Hanff, Pittsburgh, Pa.
A. R. Oltrogge, Schenectady, N. Y.
E. Scheick, New York, N. Y.
H. H. Zielinski, Schenectady, N. Y.

Cathodic Protection Subcommittee

R. M. Wainwright, *Chairman;* College of

Engineering, University of Illinois, Urbana, Ill.
A. E. Archambault New York, N. Y.
J. D. Brance Houston, Tex.
A. S. Brooks Newark, N. J.
Guy Corfield Los Angeles, Calif.
G. C. Cox Charleston, W. Va.
I. A. Dennison Washington, D. C.
I. C. Dietze Los Angeles, Calif.
L. J. Gorman New York, N. Y.
T. G. Hieronymus Kansas City, Mo.
R. J. Kuhn New Orleans, La.
D. H. Levy Dallas, Tex.
R. W. Linney Oklahoma City, Okla.
F. J. Mollerus Richland, Wash.
R. L. Rayner Detroit, Mich.
H. W. Wahlquist New York, N. Y.

ELECTROLYTIC PROCESSES SUBCOMMITTEE

W. E. Gutzwiller, *Chairman;* Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Felix Glaza Freeport, Tex.
J. D. Harper Alcoa, Tenn.
H. E. Houck Wilmington, Del.
F. L. Kaestle Schenectady, N. Y.
Rollin Kennard Butte, Mont.
F. L. Lawton Montreal, Quebec, Canada
G. H. Orcutt Wyandotte, Mich.
Waldo Porter Vancouver, Wash.
G. B. Scheer Oakland, Calif.
Joel Tompkins Massena, N. Y.

PETROLEUM REFINING AND PRODUCTION SUBCOMMITTEE

Lester Goldsmith, *Chairman;* Atlantic Refining Company, 260 South Broad Street, Philadelphia 1, Pa.
H. J. Appel New York, N. Y.
E. C. Benjamin New York, N. Y.
W. H. Dickinson Elizabeth, N. J.
J. B. Glasby Philadelphia, Pa.
E. L. Hoyle East Chicago, Ind.
D. H. Levy Dallas, Tex.
E. L. Nopper Philadelphia, Pa.

STORAGE BATTERIES SUBCOMMITTEE

H. C. Riggs, *Chairman;* Electric Storage Battery Company, 19th and Allegheny Avenue, Philadelphia 32, Pa.
J. D. Huntsberger Trenton, N. J.
L. A. Murray Providence, R. I.
E. T. Rummel Cleveland, Ohio
J. J. Unger Cleveland, Ohio
K. A. Vaughn Depew, N. Y.
H. H. Zielinski Schenectady, N. Y.

CHEMICAL INDUSTRIES SUBCOMMITTEE

L. W. Roush, *Chairman;* Union Carbide and Carbon Corporation, South Charleston, W. Va.
Felix Glaza Freeport, Tex.
E. M. Hansford Montgomery, W. Va.
J. A. Horacek Fairport Harbor, Ohio
H. E. Houck Wilmington, Del.
M. A. Hyde East Pittsburgh, Pa.
S. J. Rosch Hastings-on-Hudson, N. Y.

Electric Heating

RADIANT HEATING SUBCOMMITTEE

I. J. Barber, *Chairman;* Fostoria Pressed Steel Corporation, 1945 Bradner Street, Fostoria, Ohio
E. J. Bates Dayton, Ohio
Earl Benson Boston, Mass.
P. O. Blackmore Newark, N. J.
P. H. Bowman Chicago, Ill.
A. H. Canada Schenectady, N. Y.
C. S. Cogger Nutley, N. J.
P. H. Goodell Detroit, Mich.
J. C. Handy Baltimore, Md.
S. G. Hibben Bloomfield, N. J.
W. F. Hickes Foxboro, Mass.
J. E. Johanson St. Louis, Mo.
J. E. Kolb Pittsburgh, Pa.
E. A. Linsday Cleveland, Ohio
R. C. Machler Philadelphia, Pa.
C. L. Raynor Detroit, Mich.
C. E. Russell Philadelphia, Pa.
Lawrence Stout St. Louis, Mo.
W. H. Wannamaker Philadelphia, Pa.

INDUCTION AND DIELECTRIC HEATING SUBCOMMITTEE

W. C. Rudd, *Chairman;* 68 Lansdowne Drive, Larchmont, N. Y.
R. M. Baker Baltimore, Md.
G. P. Bosomworth Akron, Ohio
E. W. Chapin Laurel, Md.
F. T. Chesnut Trenton, N. J.
L. M. Duryee Waterbury, Conn.
J. E. Eiselein Camden, N. J.
C. W. Frick Schenectady, N. Y.
W. H. Hickok Louisville, Ky.
R. J. Hunn Wilmington, Del.
T. P. Kinn Baltimore, Md.
G. W. Klingaman Camden, N. J.
Eugene Mittleman Chicago, Ill.
William Paulin Toronto, Ont., Canada
G. W. Scott, Jr. Lancaster, Pa.
R. S. Tucker New York, N. Y.
J. T. Vaughan Cleveland, Ohio
D. E. Watts Syracuse, N. Y.
Otto Weitmann New York, N. Y.

RADIATION MEASUREMENTS ABOVE 200 MEGACYCLES SUBCOMMITTEE

R. M. Baker, *Chairman;* Westinghouse Electric Corporation, 2519 Wilkens Avenue, Baltimore 3, Md.
H. H. Beizer Fort Monmouth, N. J.
Marvin Bock Waltham, Mass.
E. W. Chapin Laurel, Md.
H. E. Dinger Washington, D. C.
J. E. Eiselein Camden, N. J.
C. W. Frick Schenectady, N. Y.
J. C. Handy Baltimore, Md.
Paul Hines Newton, Mass.
W. L. Roberts East Pittsburgh, Pa.
Ralph M. Showers Philadelphia, Pa.
H. E. Sorrows Wheaton, Md.
A. J. Vadasz Syracuse, N. Y.

Electric Welding

POWER SUPPLY FOR RESISTANCE WELDING MACHINES SUBCOMMITTEE

C. N. Clark, *Chairman;* Duquesne Light Company, 435 Sixth Avenue, Pittsburgh, Pa.
N. A. Kieb, *Vice-Chairman;* Detroit, Mich.
E. L. Bailey Highland Park, Mich.
W. K. Boice Schenectady, N. Y.
W. G. Bostwick Cincinnati, Ohio
W. W. Brumby Toronto, Ontario, Canada
J. F. Deffenbaugh Warren, Ohio
S. W. Luther Detroit, Mich.
R. S. Phair Philadelphia, Pa.
C. E. Smith Warren, Ohio
J. L. Solomon Chicago, Ill.
C. B. Stadum Buffalo, N. Y.
H. W. Tietze Newark, N. J.
H. R. Wall Jackson, Mich.
Myron Zucker Royal Oak, Mich.

RESEARCH SUBCOMMITTEE

R. C. McMaster, *Chairman;* Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio
(Personnel to be selected)

Feedback Control Systems

TERMINOLOGY AND NOMENCLATURE SUBCOMMITTEE

F. E. Crever, *Chairman;* Atomic Power Division, General Electric Company, Schenectady, N. Y.
W. R. Ahrendt College Park, Md.
H. W. Cory Milwaukee, Wis.
Paul Travers Cambridge, Mass.
A. J. Williams, Jr. Philadelphia, Pa.

General Industry Applications

MACHINE TOOLS SUBCOMMITTEE

D. R. Percival, *Chairman;* Machinery Electrification Inc., 98 Union Street, Worcester, Mass.
B. T. Anderson Rockford, Ill.
R. W. Brown Windsor, Vt.
J. M. Delfs Schenectady, N. Y.
R. T. Fenn Springfield, Vt.
L. W. Herchenroeder Pittsburgh, Pa.
J. J. Jaeger West Hartford, Conn.
E. F. Mekelburg Milwaukee, Wis.
W. J. Piper Springfield, Vt.
S. Rice Worcester, Mass.
E. J. Rivoira Cincinnati, Ohio
R. E. Stroppel Cincinnati, Ohio
W. B. Wigton Cincinnati, Ohio
T. A. Wetzel Milwaukee, Wis.

MATERIALS HANDLING SUBCOMMITTEE

S. P. Blakeman, *Chairman;* Haughton Elevator Company, 1725 Fairmount Avenue, Philadelphia, Pa.
F. W. Atz Philadelphia, Pa.
E. L. Blankenbeker Pittsburgh, Pa.
A. R. Dunne Port Hope, Ontario, Canada
D. C. Gray St. Paul, Minn.
C. P. Hamilton Schenectady, N. Y.
E. M. Hays Pittsburgh, Pa.
W. O. Land Philadelphia, Pa.
G. N. Meyers Philadelphia, Pa.
Fred A. Miller Wilmington, Del.

PULP AND PAPER INDUSTRY SUBCOMMITTEE

W. B. Baker, *Chairman;* Westinghouse Electric Corporation, Industrial Engineering Division, East Pittsburgh, Pa.
H. B. Barrow Atlanta, Ga.
G. C. Ehemann Rittman, Ohio
G. W. Knapp Schenectady, N. Y.
E. K. Murphy New York, N. Y.
E. H. Overby Savannah, Ga.
H. A. Rose Seattle, Wash.
J. L. Van Nort Cleveland, Ohio

RUBBER AND PLASTICS INDUSTRIES SUBCOMMITTEE

H. F. Snyder, *Chairman;* Goodyear Tire and Rubber Company, 1144 East Market Street, Akron, Ohio
A. T. Bacheler Buffalo, N. Y.
L. T. Blalock Dallas, Texas
B. J. Dalton Schenectady, N. Y.
K. W. John Detroit, Mich
G. V. Kullgren Akron, Ohio
J. F. Moore Toronto, Ontario, Canada
H. R. Neighbours Mishawaka, Ind.
R. G. Rudrow Wilmington, Del.
W. J. Secrest Akron, Ohio
R. E. Seddon Wilmington, Del.
A. G. Seifried Akron, Ohio
H. L. Smith New York, N. Y.
W. S. Watkins Willoughby, Ohio
B. H. Zacherle Philadelphia, Pa.

TEXTILE INDUSTRY SUBCOMMITTEE

R. J. Demartini, *Chairman;* General Electric Company, Industry Engineering Division, Schenectady 5, N. Y.
A. T. Bacheler Buffalo, N. Y.
S. A. Bobe Atlanta, Ga.
Swaffield Cowan Charlotte, N. C.
R. B. Flowers Atlanta, Ga.
A. W. Frankenfield Wilmington, Del.
H. Haley Philadelphia, Pa.
L. T. Jester Boston, Mass.
A. F. Lukens West Lynn, Mass.
V. P. Sepavich Worcester, Mass.
F. D. Snyder Boston, Mass.
H. C. Uhl Sylacauga, Alabama

Industrial Control

BIBLIOGRAPHY SUBCOMMITTEE

R. W. Jones, *Chairman;* Department of Electrical Engineering, Northwestern University, Evanston, Ill.
W. H. Elliott Milwaukee, Wis.
E. E. Moyer Troy, N. Y.
J. W. Picking Cleveland, Ohio
Walter Schaelchlin East Pittsburgh, Pa.

ELECTRONIC CONTROL SUBCOMMITTEE

H. L. Palmer, *Chairman;* General Electric Company, 1 River Road, Schenectady 5, N. Y.
F. T. Bailey Buffalo, N. Y.
H. B. Black Ampere, N. J.
L. H. Dee Schenectady, N. Y.
W. H. Elliot Milwaukee, Wis.
William Few Cleveland, Ohio
E. W. Hutton Schenectady, N. Y.
L. U. C. Kelling Schenectady, N. Y.
M. H. A. Lindsay New York, N. Y.
E. B. McDowell Schenectady, N. Y.
F. O. Nottingham Lafayette, Ind.
J. W. Picking Cleveland, Ohio
L. C. Poole Detroit, Mich.
V. J. Porter Philadelphia, Pa.
K. P. Puchlowski Pittsburgh, Pa.
W. G. Roman Buffalo, N. Y.
C. A. Schurr Cleveland, Ohio
H. I. Stanback Milwaukee, Wis.
G. F. Stark Baltimore, Md.
B. B. Stuart Waltham, Mass.
C. M. Summers Fort Wayne, Ind.
B. F. Tellkamp Milwaukee, Wis.

Working Groups:

(1). Electronic Control of D-C Motors
J. W. Picking, *Chairman;* Reliance Electric and Engineering Company, 1068–1088 Ivanhoe Road, Cleveland 10, Ohio
H. B. Black Ampere, N. J.
L. H. Dee Schenectady, N. Y.
W. H. Elliot Milwaukee, Wis.
William Few Cleveland, Ohio
L. C. Poole Detroit, Mich.
W. G. Roman Buffalo, N. Y.
H. I. Stanback Milwaukee, Wis.
B. B. Stuart Waltham, Mass.
B. F. Tellkamp Milwaukee, Wis.

(2). Photoelectric Pickup Systems
L. U. C. Kelling, *Chairman;* General Electric Company, 1 River Road, Schenectady 5, N. Y.
F. T. Bailey Buffalo, N. Y.
M. H. A. Lindsay New York, N. Y.
E. M. Pritchard Boston, Mass.
L. L. Worner Rankin, Ill.

(3). Electronic Relaying Devices
E. B. McDowell, *Chairman;* General Electric Company, 1 River Road, Schenectady 5, N. Y.
C. A. Schurr Cleveland, Ohio
B. F. Tellkamp Milwaukee, Wis.

(4). Electronic Control of A-C Power
E. W. Hutton, *Chairman;* General Electric Company, 1 River Road, Schenectady 5, N. Y.
H. B. Black Ampere, N. J.
W. H. Elliot Milwaukee, Wis.
W. G. Roman Buffalo, N. Y.
G. F. Stark Baltimore, Md.
B. F. Tellkamp Milwaukee, Wis.

REGULATORS AND FEEDBACK SYSTEMS SUBCOMMITTEE

O. W. Livingston, *Chairman;* Electronics and Regulator Control Engineering Division, General Electric Company, 1 River Road, Schenectady 5, N. Y.
H. B. Black Ampere, N. J.
S. L. Burgwin Buffalo, N. Y.
E. T. Davis Philadelphia, Pa.
W. H. Elliot Milwaukee, Wis.
William Few Cleveland, Ohio
J. W. Picking Cleveland, Ohio
B. F. Tellkamp Milwaukee, Wis.

STANDARDS SUBCOMMITTEE

J. J. O'Connor, *Chairman;* Associate Editor, *Power*, McGraw-Hill Publishing Company, 330 West 42nd Street, New York 18, N. Y.
E. L. Bailey Detroit, Mich.
J. E. Gahagan Binghamton, N. Y.
J. A. Gienger Rochester, N. Y.
F. Y. Grepe Toronto, Ontario, Canada
R. W. Kowitz Dearborn, Mich.
L. H. Matthias Milwaukee, Wis.
F. E. Strauss Oakland, Calif.

TEST CODES SUBCOMMITTEE

C. T. Evans, *Chairman;* Cutler-Hammer, Inc., 315 North 12th Street, Milwaukee, Wis.
D. K. Frost Rockford, Ill.
B. W. Jones Schenectady, N. Y.
H. E. Nason Chicago, Ill.
W. E. Pakala East Pittsburgh, Pa.
H. E. Rhoads Schenectady, N. Y.
C. A. Schaefer Milwaukee, Wis.

Industrial Power Systems

EXECUTIVE SUBCOMMITTEE

Main Committee Officers:
J. S. Gault, *Chairman;* Electrical Engineering Department, University of Michigan, Ann Arbor, Mich.
H. G. Barnett, *Vice-Chairman* East Pittsburgh, Pa.
S. A. Warner, *Secretary* New York, N. Y.

Subcommittee Chairmen:
H. G. Barnett East Pittsburgh, Pa.
D. L. Beeman Schenectady, N. Y.
C. R. Johnson New York, N. Y.
A. E. Marshall St. Louis, Mo.
T. O. Sweatt New York, N. Y.
B. F. Thomas, Jr. New York, N. Y.

POWER SUPPLY SUBCOMMITTEE

A. E. Marshall, *Chairman;* Monsanto Chemical Company, 1700 South 2nd Street, St. Louis 4, Mo.
R. T. Woodruff St. Louis, Mo.

Distribution Systems for Industrial Plants Subcommittee

H. G. Barnett, *Chairman;* Westinghouse Electric Corporation, East Pittsburgh, Pa.
J. E. Arberry Pittsburgh, Pa.
D. L. Beeman Schenectady, N. Y.
D. D. Douglass Oakland, Calif.
W. S. Gordon, Jr. Tacoma, Wash.
C. R. Johnson New York, N. Y.
C. M. Lathrop Elizabeth, N. J.
S. W. Luther Detroit, Mich.
J. E. Mellett Atlanta, Ga.
Dick Ray Tulsa, Okla.
C. C. Saunders Wilmington, Del.
R. C. Waldron Passaic, N. J.
R. M. Wilson, Jr. Schenectady, N. Y.
T. O. Zittel Lackawanna, N. Y.

Distribution Systems for Commercial Buildings Subcommittee

B. F. Thomas, Jr., *Chairman;* N. A. Lougee and Company, 120 Broadway, New York 5, N. Y.
Allan Coggeshall New York, N. Y.
L. C. McCullough New York, N. Y.
A. C. Youngson New York, N. Y.

Characteristics of Loads Subcommittee

T. O. Sweatt, *Chairman;* Wearn, Vreeland, Carlson and Sweatt, Inc., 43 Exchange Place, New York 5, N. Y.
V. E. Dodson Seattle, Wash.
K. K. Falk South Bend, Ind.
J. D. Harper Alcoa, Tenn.
C. M. Lathrop Elizabeth, N. J.
C. C. Saunders Wilmington, Del.
W. J. Secrest Akron, Ohio
T. O. Zittel Lackawanna, N. Y.

Industrial Grounding Subcommittee

D. L. Beeman, *Chairman;* General Electric Company, Schenectady 5, N. Y.
H. H. Angel Bethlehem, Pa.
J. E. Arberry Pittsburgh, Pa.
K. M. Bausch San Francisco, Calif.
Fred Heller New York, N. Y.
L. W. Roush South Charleston, W. Va.
C. C. Saunders Wilmington, Del.
J. M. Schmidt Baytown, Texas
T. O. Sweatt New York, N. Y.
H. B. Thacker East Pittsburgh, Pa.
B. F. Thomas, Jr. New York, N. Y.
S. A. Warner New York, N. Y.

Codes and Standards Subcommittee

C. R. Johnson, *Chairman;* The Port of New York Authority, Engineering Department, 111 Eighth Avenue, New York 11, N. Y.
L. W. McCullough New York, N. Y.

Mining and Metal Industry

Metal Industries Subcommittee

W. R. Harris, *Chairman;* Westinghouse Electric Corporation, Department 10-L, East Pittsburgh, Pa.
J. E. Arberry Pittsburgh, Pa.
H. W. Biskeborn Newark, Ohio
F. W. Cramer Pittsburgh, Pa.
Sam Ein Chicago, Ill.
R. H. Ellis Pittsburgh, Pa.
Cecil Farrow Cleveland, Ohio
Lanier Greer Cleveland, Ohio
L. N. Grier Pittsburgh, Pa.
W. E. Miller Schenectady, N. Y.
B. E. Price New York, N. Y.
E. G. Schlup Middletown, Ohio
F. O. Schnure Sparrows Point, Md.
Victor Siegfried Worcester, Mass.
H. I. Stanback Milwaukee, Wis.
J. R. Wickey Cleveland, Ohio

Mining Subcommittee

J. J. Fitzgibbon, *Chairman;* General Electric Company, 306 MacCorkle Avenue, Charleston 28, W. Va.
J. E. Breth Bessemer, Ala.
Graham Bright Pittsburgh, Pa.
A. B. Chafetz Carlsbad, N. Mex.
R. J. Corfield Garfield, Utah
E. W. Davis Cambridge, Mass.
J. M. Downie Erie, Pa.
J. H. Edwards New York, N. Y.
C. L. Gust Lead, S. Dak.
L. H. Harrison Birmingham, Ala.
J. G. Ivy Chicago, Ill.
L. H. James Scranton, Pa.
G. F. Johnson Michigan City, Ind.
J. Z. Linsenmeyer East Pittsburgh, Pa.
R. C. McMaster Columbus, Ohio
A. C. Muir Philadelphia, Pa.
H. P. Musser Charleston, W. Va.
M. G. Myers, Jr. Boston, Mass.
F. C. Nicholson Wilkes-Barre, Pa.
C. A. Poppino Phoenix, Arizona
B. E. Rector East Pittsburgh, Pa.
D. E. Renshaw Chicago, Ill.
L. W. Roush South Charleston, W. Va.
O. J. Swanson Gary, W. Va.
C. L. Tyler Irwin, Pa.
T. R. Weichel Wilkes-Barre, Pa.
W. G. Willson Phoenix, Arizona
C. O. Wood Chicago, Ill.

Power Division

Carrier Current

Subcommittee for Preparation of a General Interest Paper on Carrier Current

M. H. Wood, *Chairman;* Westinghouse Electric Corporation, Electronics and X-Ray Division, 2519 Wilkens Avenue, Baltimore 3, Md.
S. C. Bartlett New York, N. Y.
J. D. Booth Baltimore, Md.
L. F. Kennedy Schenectady, N. Y.

Subcommittee to Report on Application Guidance for Carrier Current

D. M. MacGregor, *Chairman;* Ebasco Services, Inc., 2 Rector Street, New York 6, N. Y.
C. W. Boadway Toronto, Ontario, Canada
T. D. Talmage Chattanooga, Tenn.

Methods of Measurement Subcommittee

E. W. Kenefake, *Chairman;* General Electric Company, Electronics Department, Syracuse, N. Y.
S. C. Bartlett New York, N. Y.
C. W. Boadway Toronto, Ontario, Canada
M. H. Wood Baltimore, Md.

High-Frequency Characteristics of Power Equipment Subcommittee

S. C. Leyland, *Chairman;* Westinghouse Electric Corporation, 95 Orange Street, Newark 2, N. J.
T. A. Cramer Schenectady, N. Y.

Carrier Current Characteristics of Transmission Lines and Systems Subcommittee

T. D. Talmage, *Chairman;* Kellogg Switchboard and Supply Company, 6650 Cicero Avenue, Chicago 38, Ill.
W. H. Blankmeyer Butte, Mont.
R. C. Ericson Hammond, Ind.
W. J. Googe Shreveport, La.
L. E. Ludekens Los Angeles, Calif.

Long Life Tubes Subcommittee

L. G. Eaton, *Chairman;* New England Power Service Company, 441 Stuart Street, Boston 16, Mass.
R. W. Beckwith Syracuse, N. Y.
L. F. Ferri Elyria, Ohio
Samuel Lubin Washington, D. C.
M. H. Wood Baltimore, Md.

Use of Microwave Equipment for Relaying, Telemetering, and Supervisory Control Subcommittee

S. C. Leyland, *Chairman;* Westinghouse Electric Corporation, 95 Orange Street, Newark 2, N. J.

Operating Experience With Carrier Current Relaying Channels Subcommittee

O. A. Starcke, *Chairman;* Kansas City Power and Light Company, Box 679, Kansas City, Mo.
T. A. Cramer Schenectady, N. Y.
J. R. Curtin Portland, Oreg.
W. J. Googe Shreveport, La.
V. J. Hayes Waterbury, Conn.
H. W. Lensner Newark, N. J.
L. E. Ludekens Los Angeles, Calif.
B. W. Storer Chicago, Ill.
Mead Warren, Jr. Alcoa, Tenn.

Insulated Conductors

Administration Subcommittee

Herman Halperin, *Chairman;* Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.
V. A. Sheals, *Vice-Chairman* Schenectady, N. Y.
C. T. Hatcher, *Secretary* New York, N. Y.
L. F. Hickernell Hastings-on-Hudson, N. Y.

Subcommittee Chairmen:
G. W. Acock Trenton, N. J.
W. A. Del Mar Yonkers, N. Y.
G. H. Fiedler Rochester, N. Y.
L. E. Fogg Phillipsdale, R. I.
M. W. Ghen Pittsburgh, Pa.
L. I. Komives Detroit, Mich.
W. T. Peirce Worcester, Mass.
R. S. Peterson Chicago, Ill.
G. M. L. Sommerman Evanston, Ill.
Gordon Thompson New York, N. Y.
H. H. Watson Bridgeport, Conn.

Standards and Publications Subcommittee

L. E. Fogg, *Chairman;* Kennecott Wire and Cable Company, Phillipsdale, R. I.
A. S. Brookes Newark, N. J.
M. H. McGrath New York, N. Y.
V. A. Sheals Schenectady, N. Y.
H. D. Short Toronto, Ontario, Canada
C. W. Zimmerer New York, N. Y.

Cable Characteristics Subcommittee

W. A. Del Mar, *Chairman;* Phelps Dodge Copper Products Company, Habirshaw Cable and Wire Division, Yonkers, N. Y.
E. D. Bent Montreal, Quebec, Canada
C. T. Hatcher New York, N. Y.
A. H. Kidder Philadelphia, Pa.
C. G. Mansfield Los Angeles, Calif.
M. H. McGrath New York, N. Y.
J. H. Neher Philadelphia, Pa.
G. B. Shanklin Schenectady, N. Y.
F. V. Smith Chicago, Ill.
E. R. Thomas New York, N. Y.
R. J. Wiseman Passaic, N. J.
F. O. Wollaston Vancouver, B. C., Canada
R. K. Woodson Kansas City, Mo.

Conductors Subcommittee

H. W. Acock, *Chairman;* J. A. Roebling's Sons, 640 South Broad Street, Trenton, N. J.
L. E. Fogg Phillipsdale, R. I.
R. C. Waldron Passaic, N. J.
G. W. Zink Yonkers, N. Y.

Insulations Subcommittee

G. M. L. Sommerman, *Chairman;* Department of Electrical Engineering, Northwestern Technological Institute, Evanston, Ill.
J. C. Balsbaugh Cambridge, Mass.
C. E. Betzer Chicago, Ill.
F. M. Clark Pittsfield, Mass.
A. S. Dana Seymour, Conn.
E. W. Greenfield Hastings-on-Hudson, N. Y.
Thorstein Larsen Baltimore, Md.
E. L. Lotz Irvington, N. J.
R. B. McKinley Bridgeport, Conn.
J. D. Piper Detroit, Mich.
R. A. Schatzel Rome, N. Y.
E. G. Sturdevant Bristol, R. I.
A. J. Warner Nutley, N. J.
K. S. Wyatt Yonkers, N. Y.

Sheaths and Coverings Subcommittee

G. H. Fiedler, *Chairman;* Rochester Gas and Electric Company, Rochester, N. Y.
C. F. Avila Boston, Mass.
C. E. Betzer Chicago, Ill.
Andrew Bodicky St. Louis, Mo.
A. S. Brookes Newark, N. J.
A. H. Kidder Philadelphia, Pa.
F. E. Kulman New York, N. Y.
A. D. Pettee Perth Amboy, N. J.
V. A. Sheals Schenectady, N. Y.
R. C. Waldron Passaic, N. J.
G. W. Zink Yonkers, N. Y.

Cable Supply Systems Subcommittee

L. I. Komives, *Chairman;* Detroit Edison Company, 2000—2d Avenue, Detroit 26, Mich.
C. F. Avila Boston, Mass.
T. J. Brosnan Buffalo, N. Y.
W. R. Bullard New York, N. Y.
H. W. Clark Washington, D. C.
D. M. Farnham Montreal, Quebec, Canada
J. D. Frantz Portland, Oreg.
C. T. Hatcher New York, N. Y.
M. J. Lowenberg Boston, Mass.
A. D. Pettee Perth Amboy, N. J.
C. S. Schifreen Philadelphia, Pa.
G. B. Shanklin Schenectady, N. Y.
H. D. Short Toronto, Ontario, Canada
C. F. Titus Jacksonville, Fla.
R. J. Wiseman Passaic, N. J.
F. O. Wollaston Vancouver, B. C., Canada
K. S. Wyatt Yonkers, N. Y.

Utilization Wiring Systems Subcommittee

H. H. Watson, *Chairman;* General Electric Company, 1285 Boston Avenue, Bridgeport 2, Conn.
E. L. Bailey Detroit, Mich.
H. G. Barnett East Pittsburgh, Pa.
A. L. Barrett Franklin, Pa.
C. M. Boardman Pittsburgh, Pa.
T. P. Branch Washington, D. C.
C. A. Finkel Passaic, N. J.
R. W. Foster Canton, N. C.
F. S. Glaza Freeport, Texas
Lester Goldsmith Philadelphia, Pa.
J. E. Huguelet Detroit, Mich.
M. J. Lowenberg Boston, Mass.
J. B. MacLean New York, N. Y.
S. J. Rosch Hastings-on-Hudson, N. Y.
R. A. Schatzel Rome, N. Y.
J. S. Waddington Brockville, Ontario, Canada
C. W. Zimmerer New York, N. Y.

Special-Purpose Cable Subcommittee

W. T. Peirce, *Chairman;* American Steel and Wire Company, Worcester, Mass.
G. W. Acock Trenton, N. J.
J. F. Atkinson Washington, D. C.
A. L. Barrett Franklin, Pa.
E. D. Bent Montreal, Quebec, Canada
E. W. Davis Cambridge, Mass.
R. A. Hopkins Knoxville, Tenn.
J. E. Huguelet Detroit, Mich.
R. H. Kolks Cincinnati, Ohio
R. B. McKinley Bridgeport, Conn.
M. L. Perry Kansas City, Mo.
F. V. Smith Chicago, Ill.
E. G. Sturdevant Bristol, R. I.
C. F. Titus Jacksonville, Fla.
R. K. Woodson Kansas City, Mo.
W. N. Zippler New York, N. Y.
G. W. Zink Yonkers, N. Y.

Accessories Subcommittee

M. W. Ghen, *Chairman;* Duquesne Light Company, 1241 Reedsdale Street, N. S. Pittsburgh 33, Pa.
P. N. Bosworth Pittsfield, Mass.
C. Christensen Melrose Park, Ill.
C. D. Eash Jackson, Mich.
J. D. Frantz Portland, Oreg.
G. G. Grissinger East Pittsburgh, Pa.
Fred Heller New York, N. Y.
J. E. Johnson Philadelphia, Pa.
R. H. Kolks Cincinnati, Ohio
L. E. Leinbach Detroit, Mich.
E. L. Lotz Irvington, N. J.
H. E. Martin Brooklyn, N. Y.
R. E. Morse New York, N. Y.
J. H. Nicholas Chicago, Ill.
Lawrence Palmer Seattle, Wash.
M. L. Perry, Jr. Kansas City, Mo.
F. P. West New York, N. Y.
D. S. Young Toronto, Ont., Canada
S. Zysk Schenectady, N. Y.

Structures Subcommittee

R. S. Peterson, *Chairman;* Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.
M. J. Andrews Los Angeles, Calif.

C. E. Baugh San Francisco, Calif.
Andrew Bodicky St. Louis, Mo.
T. J. Brosnan Buffalo, N. Y.
H. W. Clark Washington, D. C.
C. D. Eash Jackson, Mich.
G. H. Fiedler Rochester, N. Y.
Lawrence Palmer Seattle, Wash.
L. G. Smith Baltimore, Md.
F. P. West New York, N. Y.
R. K. Woodson Kansas City, Mo.

Tests and Measurements Subcommittee

Gordon Thompson, *Chairman;* Electrical Testing Laboratories, Inc., 2 West End Avenue, New York 21, N. Y.
J. C. Balsbaugh Cambridge, Mass.
A. L. Brownlee Chicago, Ill.
A. S. Dana Seymour, Conn.
E. W. Davis Cambridge, Mass.
W. A. Del Mar Yonkers, N. Y.
E. W. Greenfield Hastings-on-Hudson, N. Y.
Thorstein Larsen Baltimore, Md.
J. C. Parker Memphis, Tenn.
G. M. L. Sommerman Evanston, Ill.
R. F. Tener Washington, D. C.
E. R. Thomas New York, N. Y.
R. C. Waldron Passaic, N. J.
C. W. Zimmerer New York, N. Y.

Power Generation

Prime Movers Subcommittee

B. G. A. Skrotzki, *Chairman;* Associate Editor, *Power*, 330 West 42d Street, New York 18, N. Y.
J. A. Brooks New York, N. Y.
E. P. Bryant Los Angeles, Calif.
A. D. Caskey Chicago, Ill.
Michael Pope New York, N. Y.
C. S. Randall Washington, D. C.
R. R. Wisner Boston, Mass.

Speed Governing Subcommittee

J. B. McClure, *Chairman;* General Electric Company, Central Station Engineering Division, Schenectady 5, N. Y.
R. E. Appleyard Milwaukee, Wis.
C. P. Almon, Jr. Chattanooga, Tenn.
R. M. Beville Chicago, Ill.
A. P. Hayward Pittsburgh, Pa.
T. H. Mawson Birmingham, Ala.
G. H. McDaniel New York, N. Y.
F. L. Reinmann Michigan City, Ind.

Excitation Systems Subcommittee

A. J. Krupy, *Chairman;* Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.
J. B. McClure, *Vice-Chairman* Schenectady, N. Y.
J. E. Barkle, Jr. East Pittsburgh, Pa.
E. F. Dissmeyer Jackson, Mich.
Alex. Dovjikov Portland, Oreg.
C. B. Fontaine, Jr. Lynn, Mass.
L. A. Kilgore East Pittsburgh, Pa.
J. H. Kinghorn New York, N. Y.
H. A. P. Langstaff Pittsburgh, Pa.
T. B. Montgomery Milwaukee, Wis.
F. D. Troxel Chicago, Ill.
R. L. Witzke East Pittsburgh, Pa.

Station Design Subcommittee

H. R. Harris, *Chairman;* The Detroit Edison Company, 2000—2d Avenue, Detroit 26, Mich.
H. E. Deardorff Dayton, Ohio
C. A. Harrington Cleveland, Ohio
D. R. Pattison Johnstown, Pa.
W. W. Perry Binghamton, N. Y.
R. R. Wisner Boston, Mass.

Hydroelectric Systems Subcommittee

F. L. Lawton, *Chairman;* Aluminum Laboratories, Ltd., 1800 Sun Life Building, Montreal, Quebec, Canada
S. M. Denton Denver, Colo.
J. T. Madill Arvida, Quebec, Canada
E. F. Maryatt San Francisco, Calif.
A. L. Pollard Seattle, Wash.
G. R. Woodman Los Angeles, Calif.

Pacific Coast Subcommittee

E. P. Bryant, *Chairman;* Department of Water and Power, City of Los Angeles, 207 South Broadway, Los Angeles 12, Calif.
S. M. Denton Denver, Colo.
Alex Dovjikov Portland, Ore.
E. F. Maryatt San Francisco, Calif.
A. L. Pollard Seattle, Wash.
G. R. Woodman Los Angeles, Calif.

Protective Devices

Fault Limiting Devices Subcommittee

E. G. Norell, *Chairman;* Sargent and Lundy, 140 South Dearborn Street, Chicago 3, Ill.
J. P. Barron Dallas, Texas
V. J. Cissna Chattanooga, Tenn.
J. A. Coleman Boston, Mass.
G. B. Dodds Pittsburgh, Pa.
E. T. B. Gross Chicago, Ill.
W. D. Hardaway Denver, Colo.
H. W. Hartzell Jackson, Mich.
E. M. Hunter Schenectady, N. Y.
P. A. Jeanne New York, N. Y.
A. A. Johnson East Pittsburgh, Pa.
W. A. Lewis, Jr. Chicago, Ill.
F. R. Longley Springfield, Mass.
Cort Lowerison Los Angeles, Calif.
Corbett McLean Portland, Oreg.
H. D. Ruger Sparrows Point, Md.
O. L. Sidenfaden Los Angeles, Calif.
W. T. Smith Arlington, Va.
S. S. Watkins New York, N. Y.

Project 1: Application Guide on Methods of Grounding Transmission Systems
E. N. Hunter, *Chairman* Schenectady, N. Y.
H. W. Hartzell Jackson, Mich.
A. A. Johnson East Pittsburgh, Pa.
R. E. Neidig Reading, Pa.

Project 2: Application Guide for the Grounding of Synchronous Generator Systems
A. A. Johnson, *Chairman* East Pittsburgh, Pa.
E. M. Hunter Schenectady, N. Y.
D. M. MacGregor New York, N. Y.
W. E. Marter Pittsburgh, Pa.
E. G. Norell Chicago, Ill.
W. T. Smith Arlington, Va.

Project 3: Bibliography of Literature on Grounding
E. T. B. Gross, *Chairman* Chicago, Ill.
J. E. Clem Schenectady, N. Y.

Project 4: Guide for Application of Ground-Fault Neutralizers
J. E. Clem, *Chairman* Schenectady, N. Y.
H. H. Brown Cedar Rapids, Iowa
S. S. Cook Sharon, Pa.
N. E. Dillow Schenectady, N. Y.
W. D. Hardaway Denver, Colo.
R. E. Neidig Reading, Pa.
P. B. Speer Minneapolis, Minn.

Project 5: Power System Fault Control
F. R. Longley, *Chairman* Springfield, Mass.
J. O. Coleman Boston, Mass.
F. H. Kierstead Pittsfield, Mass.
L. B. LeVesconte Chicago, Ill.
H. F. Lindemuth New York, N. Y.
E. L. Michelson Chicago, Ill.
L. E. Sauer Sharon, Pa.

Lightning Protective Devices Subcommittee

E. H. Yonkers, *Chairman;* Joslyn Manufacturing and Supply Company, 969 West 37th Place, Chicago 9, Ill.
J. E. Clem Schenectady, N. Y.
L. M. Connors Toronto, Ont., Canada
H. A. Cornelius Chicago, Ill.
F. M. Defandorf Washington, D. C.
G. K. Ditlow Washington, D. C.
J. R. Eaton Lafayette, Ind.
T. I. Eldridge Philadelphia, Pa.
I. W. Gross New York, N. Y.
E. H. Grosser Chicago, Ill.
H. W. Hartzell Jackson, Mich.
T. H. Mawson Birmingham, Ala.
W. A. McMorris Pittsfield, Mass.
A. M. Opsahl East Pittsburgh, Pa.
H. L. Rorden Portland, Oreg
A. H. Schirmer New York, N. Y.
H. O. Stoelting So. Milwaukee, Wis.
J. M. Towner Baltimore, Md.

Project 1: Application Guide of Methods for Lightning Protection of Substations
H. A. Cornelius, *Chairman* Chicago, Ill.
Harris Barber Boston, Mass.
H. W. Hartzell Jackson, Mich.
S. B. Howard Pittsfield, Mass.
E. L. Jarrett Pittsburgh, Pa.
R. H. Mertz Detroit, Mich.
A. M. Opsahl East Pittsburgh, Pa.
E. R. Whitehead Chicago, Ill.

Project 10: Recovery Voltage Characteristics of Distribution Systems
R. L. Witzke, *Chairman* East Pittsburgh, Pa.
G. K. Ditlow Washington, D. C.
I. B. Johnson Schenectady, N. Y.
L. M. Olmstead Pittsburgh, Pa.
M. A. Polster Baltimore, Md.

Co-ordination of Insulation Subcommittee

J. E. Clem, *Chairman;* Central Station Engineering Division, General Electric Company, Schenectady 5, N. Y.

Relays

Project Committee on Bibliography of Relay Literature

E. T. B. Gross, *Chairman* and *Sponsor;* Illinois Institute of Technology, 3300 Federal Street, Chicago 16, Ill.
S. Goldsmith Cincinnati, Ohio
C. E. Parks Indianapolis, Ind.
C. L. Smith Rochester, N. Y.

Project Committee on Generator Protection

H. R. Paxson, *Chairman* and *Sponsor;* Philadelphia Electric Company, 900 Sansom Street, Philadelphia 5, Pa.
L. L. Draper Los Angeles, Calif.
L. L. Fountain East Pittsburgh, Pa.
E. T. B. Gross Chicago, Ill.
B. C. Hicks Montreal, Quebec, Canada
L. F. Kennedy Schenectady, N. Y.
S. C. Leyland Newark, N. J.
H. F. Lindemuth New York, N. Y.
W. E. Marter Pittsburgh, Pa.
J. B. McClure Schenectady, N. Y.
A. J. McConnell Schenectady, N. Y.
C. E. Parks Indianapolis, Ind.
F. C. Poage New York, N. Y.
L. T. Rosenberg Milwaukee, Wis.
H. P. Sleeper Newark, N. J.
C. L. Smith Rochester, N. Y.

Project Committee on Co-ordination of Construction and Protection of Distribution Circuits (Joint with Distribution Subcommittee and Edison Electric Institute)

G. B. Dodds, AIEE *Chairman* and *Sponsor;* Duquesne Light Company, 435 Sixth Avenue, Pittsburgh 19, Pa.
R. O. Askey Chicago, Ill.
G. G. Auer Schenectady, N. Y.
T. J. Brosnan Buffalo, N. Y.
Harold Cole Detroit, Mich.
W. B. Fisk, Jr. New York, N. Y.
C. L. Headley Baltimore, Md.
Cort Lowerison Los Angeles, Calif.
H. F. Ostman St. Louis, Mo.
J. S. Parsons East Pittsburgh, Pa.
C. L. Smith Rochester, N. Y.
C. J. Beller, EEI *Chairman* and *Sponsor;* Cleveland Electric Illuminating Company, 75 Public Square, Cleveland 1, Ohio
G. H. Fiedler Rochester, N. Y.
G. E. Dean Newark, N. J.
W. P. Holben Pittsburgh, Pa.
A. L. Malmstrom Detroit, Mich.

Project Committee on Revision of Standards for Power Relays

S. C. Leyland, *Chairman* and *Sponsor;* Westinghouse Electric Corporation, 95 Orange Street, Newark 2, N. J.
R. E. Cordray Philadelphia, Pa.
V. L. Cox Philadelphia, Pa.
L. L. Fountain East Pittsburgh, Pa.
W. A. Lewis Chicago, Ill.
J. R. Linders Cleveland, Ohio
E. L. Michelson Chicago, Ill.
W. A. Morgan Denver, Colo.
H. P. Sleeper Newark, N. J.
G. S. Steeb Buffalo, N. Y.

Project Committee on Transmission-Line Protection

J. H. Kinghorn, *Chairman* and *Sponsor;* American Gas and Electric Service Corporation, 30 Church Street, New York 7, N. Y.
L. J. Audlin Syracuse, N. Y.
J. E. Barkle, Jr. East Pittsburgh, Pa.
W. R. Brownlee Jackson, Mich.
B. C. Hicks Montreal, Quebec, Canada
W. A. Lewis Chicago, Ill.
W. E. Marter Pittsburgh, Pa.
A. J. McConnell Schenectady, N. Y.
M. S. Merritt Chattanooga, Tenn.
E. L. Michelson Chicago, Ill.
C. E. Parks Indianapolis, Ind.
K. N. Reardon Pittsburgh, Pa.

Project Committee on Electronic Relay Applications

A. J. McConnell, *Chairman* and *Sponsor;* General Electric Company, Schenectady 5, N. Y.
J. E. Barkle, Jr. East Pittsburgh, Pa.
R. J. Cooper Atlanta, Ga.
F. S. Fehr Reading, Pa.
L. F. Ferri Elyria, Ohio
E. L. Harder East Pittsburgh, Pa.
J. H. Kinghorn New York, N. Y.
D. M. MacGregor New York, N. Y.
E. L. Michelson Chicago, Ill.
E. G. Ratz Hamilton, Ontario, Canada

Project Committee on Relaying of Interconnections Between Industrial and Utility Generating Systems

K. N. Reardon, *Chairman* and *Sponsor;* West Penn Power Company, 14 Wood Street, Pittsburgh, Pa.
J. E. Barkle, Jr. East Pittsburgh, Pa.
G. E. Dana Binghamton, N. Y.
F. S. Fehr Reading, Pa.
T. R. Halman Detroit, Mich.
J. R. Linders Lakewood, Ohio

Project Committee on Relaying Performance of Current Transformers (Emphasis on High Impedance Secondary Types)

W. E. Marter, *Chairman* and *Sponsor;* Duquesne Light Company, 435—6th Avenue, Pittsburgh 19, Pa.
J. E. Barkle East Pittsburgh, Pa.
J. E. Clem Schenectady, N. Y.
R. E. Cordray Philadelphia, Pa.
W. K. Dickinson Lynn, Mass.
T. R. Halman Detroit, Mich.
W. A. Lewis Chicago, Ill.
W. K. Sonnemann Newark, N. J.
E. C. Wentz Sharon, Pa.

Project Committee on Remote Tripping Schemes

H. P. Sleeper, *Chairman* and *Sponsor;* Public Service Gas and Electric Company, 80 Park Place, Newark 2, N. J.
J. L. Blackburn Newark, N. J.
M. A. Bostwick Portland, Oreg.
T. A. Cramer Schenectady, N. Y.
Sidney Goldsmith Cincinnati, Ohio
G. W. Hampe Chicago, Ill.
V. J. Hayes Waterbury, Conn.
S. C. Leyland Newark, N. J.

Project Committee on Pilot Wires

H. F. Lindemuth, *Chairman* and *Sponsor;* Consolidated Edison Company of New York, Inc., 4 Irving Place, New York 3, N. Y.
M. A. Bostwick Portland, Ore.
J. L. Davidson, Jr. Mineola, N. Y.
W. E. Marter Pittsburgh, Pa.
A. J. McConnell Schenectady, N. Y.
J. L. McKee New York, N. Y.
G. W. McKenna Philadelphia, Pa.
E. L. Michelson Chicago, Ill.
W. K. Sonnemann Newark, N. J.

Project Committee on Effect of Vibration and Shock on Relays

C. E. Asbury, *Chairman* and *Sponsor;* Commonwealth Services, Inc., 212 West Michigan Avenue, Jackson, Mich.
R. E. Cordray Philadelphia, Pa.
M. A. Faucett Urbana, Ill.
T. R. Halman Detroit, Mich.
H. F. Lindemuth New York, N. Y.
W. K. Sonnemann Newark, N. J.
G. S. Steeb Buffalo, N. Y.
R. I. Ward Chicago, Ill.

Project Committee on Test Methods

G. E. Dana, *Chairman* and *Sponsor;* New York State Electric and Gas Corporation, 62 Henry Street, Binghamton, N. Y.
R. E. Cordray Philadelphia, Pa.
L. F. Ferri Elyria, Ohio
T. R. Halman Detroit, Mich.
J. E. Lange Pittsburgh, Pa.
R. A. Larner Fort Worth, Texas

W. A. Morgan Denver, Colo.
W. K. Sonnemann Newark, N. J.

Rotating Machinery

Administrative Subcommittee

W. R. Hough, *Chairman*, Reliance Electric and Engineering Company, 1068–1088 Ivanhoe Road, Cleveland 10, Ohio
C. G. Veinott, *Vice-Chairman* Lima, Ohio
J. L. Fuller, *Secretary* Cleveland, Ohio
R. E. Arnold West Lynn, Mass.
B. H. Caldwell Schenectady, N. Y.
James DeKiep Minneapolis, Minn.
J. W. Jones Philadelphia, Pa.
I. M. Levy Dayton, Ohio
S. S. Wolff St. Louis, Mo.

Synchronous Machinery Subcommittee

James DeKiep, *Chairman;* Electric Machinery Manufacturing Company, 1331 Tyler Street, Minneapolis 13, Minn.
Sterling Beckwith Milwaukee, Wis.
J. F. Calvert Evanston, Ill.
S. B. Crary Schenectady, N. Y.
L. O. Dorfman New York, N. Y.
E. L. Harder East Pittsburgh, Pa.
J. W. Jones Philadelphia, Pa.
C. E. Kilbourne Schenectady, N. Y.
L. B. LeVesconte Chicago, Ill.
M. R. Lory East Pittsburgh, Pa.
J. G. Noest New York, N. Y.
E. I. Pollard Ridgway, Pa.
J. H. Vivian Los Angeles, Calif.
S. S. Wolff St. Louis, Mo.

Induction Machinery Subcommittee

S. S. Wolff, *Chairman;* Century Electric Company, 1806 Pine Street, St. Louis 3, Mo.
R. E. Arnold West Lynn, Mass.
E. L. Bailey Detroit, Mich.
E. C. Barnes Cleveland, Ohio
C. F. Cameron Stillwater, Okla.
S. F. Henderson Buffalo, N. Y.
C. J. Koch Schenectady, N. Y.
I. M. Levy Dayton, Ohio
T. C. Lloyd Springfield, Ohio
R. C. Moore Milwaukee, Wis.
J. G. Noest New York, N. Y.
C. P. Potter St. Louis, Mo.
F. C. Rushing Buffalo, N. Y.
P. H. Trickey Finderne, N. J.
F. M. Winterhalter Norwood, Ohio

D-C Machinery Subcommittee

B. H. Caldwell, *Chairman;* General Electric Company, 1 River Road, Schenectady 5, N. Y.
M. A. Baker Fort Wayne, Ind.
C. F. Cobb Cincinnati, Ohio
A. G. Darling Schenectady, N. Y.
W. H. Fifer Washington, D. C.
Lanier Greer Cleveland, Ohio
C. B. Hathaway Buffalo, N. Y.
L. H. Hildebrandt Dayton, Ohio
H. E. Koenig Urbana, Ill.
R. Lamborn Erie, Pa.
Paul Lebenbaum, Jr. Lynn, Mass.
Clarence Lynn East Pittsburgh, Pa.
K. Martinez Seattle, Wash.
A. T. McClinton Washington, D. C.
W. E. Meserve Ithaca, N. Y.
J. G. Noest New York, N. Y.
L. G. Opel Buffalo, N. Y.
J. H. Schneider Ridgway, Pa.
J. F. Sellers Milwaukee, Wis.
P. H. Trickey Finderne, N. J.
S. S. Wolff St. Louis, Mo.

Single-Phase and Fractional-Horsepower Subcommittee

I. M. Levy, *Chairman;* Delco Products Division, General Motors Corporation, Dayton, Ohio
W. R. Appleman Dayton, Ohio
C. F. Cameron Stillwater, Okla.
J. S. Gault Ann Arbor, Mich.
E. E. Kimberly Columbus, Ohio
T. C. Lloyd Springfield, Ohio
C. F. Miller Baltimore, Md.
R. F. Munier St. Louis, Mo.
C. P. Potter St. Louis, Mo.
L. C. Schaefer Lima, Ohio
M. L. Schmidt Fort Wayne, Ind.
P. H. Trickey Finderne, N. J.
C. G. Veinott Lima, Ohio
S. S. Wolff St. Louis, Mo.

Test Code Subcommittee

R. E. Arnold, *Chairman;* General Electric Company, 920 Western Avenue, West Lynn, Mass.
J. L. Fuller Cleveland, Ohio
J. S. Gault Ann Arbor, Mich.
Clarence Lynn East Pittsburgh, Pa.
H. C. Marcroft Lancaster, Pa.
R. F. Munier St. Louis, Mo.
E. B. Paxton Schenectady, N. Y.
E. I. Pollard Ridgway, Pa.

Insulation Subcommittee

J. W. Jones, *Chairman;* Philadelphia Electric Company, Edison Building, Philadelphia 5, Pa.
L. J. Berberich East Pittsburgh, Pa.
E. B. Curdts Philadelphia, Pa.
E. F. Dissmeyer Jackson, Mich.
Orville Fawcett Pittsburgh, Pa.
D. D. Higgins Chicago, Ill.
J. L. Kuehlthau Milwaukee, Wis.
H. C. Marcroft Lancaster, Pa.
G. L. Moses East Pittsburgh, Pa.
E. I. Pollard Ridgway, Pa.
E. H. Povey Belmont, Mass.
V. E. Schlossberg East Chicago, Ind.
J. B. Swering Hartford, Conn.
H. R. Tomlinson Boston, Mass.
A. L. Van Emden Washington, D. C.
R. W. Wieseman Schenectady, N. Y.

Substations

Executive Subcommittee

R. C. Ericson, *Chairman;* Northern Indiana Public Service Company, 5265 Hohman Avenue, Hammond, Ind.
M. V. Eardley Los Angeles, Calif.
N. G. Larson Chicago, Ill.
G. S. Lunge Schenectady, N. Y.
M. E. Reagan East Pittsburgh, Pa.
K. L. Wheeler Cleveland, Ohio

Automatic and Supervisory Control Subcommittee

M. E. Reagan, *Chairman;* Switchboard Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa.
Herman Bany Philadelphia, Pa.
R. O. Bell Milwaukee, Wis.
B. D. Dexter San Francisco, Calif.
W. M. Larson Minneapolis, Minn.
J. L. McKee New York, N. Y.

Distribution and Conversion Substation Subcommittee

M. V. Eardley, *Chairman;* Department of Water and Power, City of Los Angeles, Los Angeles 54, Calif.
Herman Bany Philadelphia, Pa.
R. O. Bell Milwaukee, Wis.
C. C. Crane Madison, Wis.
G. P. Fallon Baltimore, Md.
E. M. Hunter Schenectady, N. Y.
I. S. Mendenhall Detroit, Mich.

Transmission Substation Subcommittee

I. S. Mendenhall, *Chairman;* The Detroit Edison Company, 2000 Second Avenue, Detroit 26, Mich.
Harris Barber Boston, Mass.
F. J. Berger Philadelphia, Pa.
H. P. Cadario Toronto, Ontario, Canada
Marino Fraresso Toronto, Ontario, Canada
H. F. Gidlund Denver, Colo.
E. M. Hunter Schenectady, N. Y.
S. C. Killian Chicago, Ill.
N. G. Larson Chicago, Ill.
W. M. McCauley Greenburg, Pa.
D. C. Millard Denver, Colo.
J. H. Rixse, Jr. Washington, D. C.
W. S. Scheering Springfield, Mass.

Working Group on Device Function Numbers

Herman Bany, *Chairman;* General Electric Company, 6901 Elmwood Avenue, Philadelphia 42, Pa.
L. B. LeVesconte Chicago, Ill.
M. E. Reagan East Pittsburgh, Pa.
M. S. Schneider Cincinnati, Ohio

Working Group on Substation Grounding Practice

H. F. Gidlund, *Chairman;* Public Service Company of Colorado, 810—15th Street, Denver 2, Colo.
F. J. Berger Philadelphia, Pa.
M. K. Brown Buffalo, N. Y.
F. R. Longley Springfield, Mass.
J. M. Towner Baltimore, Md.

Working Group on Rectifier Switchgear

M. E. Reagan, *Chairman;* Switchgear Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa.
D. C. Hoffman Philadelphia, Pa.

Switchgear

Circuit Breaker Subcommittee

R. L. Webb, *Chairman;* Consolidated Edison Company of New York Inc., 4 Irving Place, New York 3, N. Y.
J. A. Elzi Jackson, Mich.
R. M. Ferrill Chattanooga, Tenn.
W. D. Hardaway Denver, Colo.
A. W. Hill East Pittsburgh, Pa.
M. H. Hobbs East Pittsburgh, Pa.
C. L. Killgore Denver, Colo.
F. A. Lane New York, N. Y.
W. G. Lewis Boston, Mass.
F. W. McCloska Chicago, Ill.
W. J. McLachlan Schenectady, N. Y.
A. Van Ryan South Milwaukee, Wis.
J. H. Vivian Los Angeles, Calif.
C. E. Winegartner Cleveland, Ohio
J. D. Wood Philadelphia, Pa.
J. C. Woods Chicago, Ill.
B. W. Wyman Philadelphia, Pa.

Working Groups:

(1). Automatic Circuit Reclosers

Anthony Van Ryan, *Chairman;* Line Material Company, Kyle Products Plant, 9th and Marion Avenues, South Milwaukee, Wis.
C. E. Asbury Jackson, Mich.
L. L. Baird Philadelphia, Pa.
Chase Hutchinson New York, N. Y.
H. H. Rudd Greensburg, Pa.
J. M. Wallace East Pittsburgh, Pa.
C. E. Winegartner Cleveland, Ohio

(2). Low-Voltage Air Circuit Breakers

J. D. Wood, *Chairman;* I.T.E. Circuit Breaker Company, 19th and Hamilton Streets, Philadelphia 30, Pa.
G. G. Grissinger East Pittsburgh, Pa.
C. L. Killgore Denver, Colo.
R. G. Meyerand St. Louis, Mo.
V. E. Schlossberg East Chicago, Ill.
J. W. Timmerman, Jr. Milwaukee, Wis.
J. C. Woods Chicago, Ill.
B. W. Wyman Philadelphia, Pa.
S. W. Zimmerman Ithaca, N. Y.

(3). Power Circuit Breakers

A. W. Hill, *Chairman;* Westinghouse Electric Corporation, East Pittsburgh, Pa.
R. M. Bennett Philadelphia, Pa.
J. A. Elzi Jackson, Mich.
R. M. Ferrill Chattanooga, Tenn.
S. B. Griscom East Pittsburgh, Pa.
W. D. Hardaway Denver, Colo.
C. L. Killgore Denver, Colo.
W. G. Lewis Boston, Mass.
J. H. Vivian Los Angeles, Calif.
J. D. Wood Philadelphia, Pa.
C. A. Woodrow Schenectady, N. Y.

Switchgear Assemblies Subcommittee

C. P. West, *Chairman;* Westinghouse Electric Corporation, East Pittsburgh, Pa.
J. M. Geiger Buffalo, N. Y.
C. L. Killgore Denver, Colo.
M. G. Lewis San Francisco, Calif.
F. W. McCloska Chicago, Ill.
E. F. Miller Davenport, Iowa
G. M. Reed Philadelphia, Pa.
Garland Stamper Dayton, Ohio
B. K. Sturgis Philadelphia, Pa.
J. W. Timmerman, Jr. Waukesha, Wis.
W. F. Wetmore Detroit, Mich.

Switches, Fuses and Insulators Subcommittee

K. J. C. Falck, *Chairman;* Philadelphia Electric Company, 900 Sansom Street, Philadelphia 7, Pa.
T. E. Curtis Hampton, Ga.
A. H. Powell Philadelphia, Pa.
R. M. Smith Greensburg, Pa.
J. M. Wallace East Pittsburgh, Pa.
J. C. Woods Chicago, Ill.

System Engineering

Administrative Subcommittee

Robert Brandt, *Chairman;* New England Power Company, 441 Stuart Street, Boston 16, Mass.
C. P. Almon, Jr. Chattanooga, Tenn.
W. B. Fisk New York, N. Y.
H. L. Harrington Buffalo, N. Y.
C. B. Kelley Des Moines, Iowa
H. A. Lott Los Angeles, Calif.
O. W. Manz, Jr. New York, N. Y.
C. B. Mayott Hartford, Conn.
C. N. Metcalf New York, N. Y.
C. W. Watchorn Baltimore, Md.

System Planning Subcommittee

W. B. Fisk, *Chairman;* Consolidated Edison Company of New York, Inc., 4 Irving Place, New York 3, N. Y.
C. G. Adams Schenectady, N. Y.
O. E. Charlton Birmingham, Ala.
A. G. Dewars Minneapolis, Minn.
A. P. Fugill Detroit, Mich.
R. G. Hooke Newark, N. J.
L. R. Janes Chicago, Ill.
C. L. Killgore Denver, Colo.
H. J. Klumb Rochester, N. Y.
A. A. Kroneberg Los Angeles, Calif.
R. F. Lawrence East Pittsburgh, Pa.
W. H. Osterle Pittsburgh, Pa.
H. P. St. Clair New York, N. Y.
G. F. Switzer Indianapolis, Ind.
J. J. Tesar Cleveland, Ohio
D. C. Vaughan Washington, D. C.
R. M. Walker El Paso, Texas
Matthew Ward Toronto, Ontario, Canada

System Operations Subcommittee

C. B. Kelley, *Chairman;* Interchange Power Service, P. O. Box 616, Des Moines, Iowa
F. A. Andrews Baltimore, Md.
E. C. Brown Hartford, Conn.
O. A. Demuth Portland, Oreg.
G. D. Floyd Toronto, Ontario, Canada
S. M. Hamill, Jr. Cincinnati, Ohio
A. C. Hartranft Philadelphia, Pa.
W. R. Johnson San Francisco, Calif.
J. C. Jones Portland, Oreg.
O. W. Manz, Jr. New York, N. Y.
W. E. Montgomery Los Angeles, Calif.
Noel Pike Phoenix, Ariz.
G. M. Tatum Richmond, Va.

System Economics Subcommittee

C. W. Watchorn, *Chairman;* Pennsylvania Water and Power Company, 1611 Lexington Building, Baltimore, Md.
E. C. Brown Hartford, Conn.
E. E. George New York, N. Y.
A. P. Hayward Pittsburgh, Pa.
N. M. Lovell Tucson, Ariz.
H. P. Peters Atlanta, Ga.
H. W. Phillips Philadelphia, Pa.
R. T. Purdy Chicago, Ill.
J. A. Rose Newark, N. J.
J. B. Ward Lafayette, Ind.
A. L. Williams Los Angeles, Calif.

System Controls Subcommittee

C. P. Almon, Jr., *Chairman;* Tennessee Valley Authority, Chattanooga 4, Tenn.
W. R. Brownlee Jackson, Mich.
D. H. Cameron Kansas City, Mo.
R. F. Lawrence East Pittsburgh, Pa.
G. H. McDaniel New York, N. Y.
C. N. Metcalf New York, N. Y.
S. B. Morehouse Philadelphia, Pa.
G. S. Whitlow St. Louis, Mo.

Interconnection Contracts Subcommittee

C. W. Mayott, *Chairman;* Hartford Electric Light Company, 266 Pearl Street, Hartford, Conn.
Bradley Cozzens Los Angeles, Calif.
E. D. Early Birmingham, Ala.
E. E. George New York, N. Y.
M. H. Lovelady Corpus Christi, Tex.
G. H. McDaniel New York, N. Y.

Transformers

Co-ordinated Study of Life of Transformer Insulation Subcommittee

J. L. Cantwell, *Chairman;* General Electric Company, 100 Woodlawn Avenue, Pittsfield, Mass.

C. E. Arntzen	East Pittsburgh, Pa.
F. M. Clark	Pittsfield, Mass.
J. F. Dexter	Midland, Mich.
C. F. Hill	East Pittsburgh, Pa.
Myron Kin	Midland, Mich.
V. M. Montsinger	Pittsfield, Mass.
T. D. Reimers	New York, N. Y.
W. W. Satterlee	Sharon, Pa.
W. M. Terry, Jr.	Pittsburgh, Pa.
F. J. Vogel	Chicago, Ill.
H. G. Zambell	Pittsburgh, Pa.

Instrument Transformers Subcommittee

J. E. Clem, *Chairman;* Central Station Engineering Division, General Electric Company, Schenectady 5, N. Y.

Herman Bany	Philadelphia, Pa.
J. H. Chiles	Sharon, Pa.
R. E. Cordray	Philadelphia, Pa.
F. E. Davis, Jr.	Jackson, Mich.
K. J. C. Falck	Philadelphia, Pa.
R. E. Franck	Lynn, Mass.
J. M. Geiger	Buffalo, N. Y.
T. R. Halman	Detroit, Mich.
E. K. Huntington	Rochester, N. Y.
L. F. Kennedy	Schenectady, N. Y.
W. E. Marter	Pittsburgh, Pa.
E. V. Sayles	Jackson, Mich.
J. P. Scott	St. Louis, Mo.
F. B. Silsbee	Washington, D. C.
W. K. Sonnemann	Newark, N. J.
W. M. Terry, Jr.	Pittsburgh, Pa.
E. C. Wentz	Sharon, Pa.
C. A. Woods	East Pittsburgh, Pa.

AIEE Papers Subcommittee

J. E. Clem, *Chairman;* Central Station Engineering Division, General Electric Company, Schenectady 5, N. Y.

Magnetization Characteristics of Transformers Subcommittee

J. E. Clem, *Chairman;* Central Station Engineering Divisions, General Electric Company, Schenectady 5, N. Y.

J. A. Elzi	Jackson, Mich.
T. D. Gordy	Pittsfield, Mass.
J. H. Kinghorn	New York, N. Y.
W. E. Marter	Pittsburgh, Pa.
A. J. Maslin	Sharon, Pa.
A. H. Powell	Philadelphia, Pa.
W. C. Sealey	Milwaukee, Wis.
J. M. Wallace	East Pittsburgh, Pa.

Revision of Dielectric Tests Subcommittee

F. J. Vogel, *Chairman;* Illinois Institute of Technology, Chicago, Ill.

V. F. Christen	St. Louis, Mo.
I. W. Gross	New York, N. Y.
J. H. Hagenguth	Pittsfield, Mass.
D. M. MacGregor	New York, N. Y.
W. R. McCarty	St. Louis, Mo.
J. R. Meador	Pittsfield, Mass.
C. W. Miller	Sharon, Pa.
V. M. Montsinger	Pittsfield, Mass.
W. C. Sealey	Milwaukee, Wis.
W. L. Teague	Sharon, Pa.

Guides for Operation and Maintenance of Dry-Type Transformers with Class B Insulation

J. A. Adams, *Chairman;* Philadelphia Electric Company, 900 Sansom Street, Philadelphia 5, Pa.

G. J. Johnston	Pittsburgh, Pa.
T. D. Reimers	New York, N. Y.
T. E. Rodhouse	Pittsfield, Mass.
W. W. Satterlee	Sharon, Pa.
H. H. Wagner	Cannonsburg, Pa.
C. E. Winegartner	Cleveland, Ohio

Co-ordination of Insulation Subcommittee

J. E. Clem, *Chairman;* Central Station Engineering Division, General Electric Company, Schenectady 5, N. Y.

Electronic Power Converters Subcommittee

W. C. Sealey, *Chairman;* Allis-Chalmers Manufacturing Company, Post Office Box 512, Milwaukee 1, Wis.

Methods of Making Temperature Tests on Transformers Subcommittee

J. E. Clem, *Chairman;* General Electric Company, Central Station Engineering Division, Schenectady 5, N. Y.

J. A. Adams	Philadelphia, Pa.
M. F. Beavers	Pittsfield, Mass.
M. K. Brown	Buffalo, N. Y.
H. B. Keath	St. Louis, Mo.
A. J. Maslin	Sharon, Pa.
W. H. Mutschler	Pittsburgh, Pa.

Power Factor Measurements Subcommittee

J. B. Hodtum, *Chairman;* Allis-Chalmers Manufacturing Company, N. S. Station, Pittsburgh 33, Pa.

Audible Noise in Transformers Subcommittee

J. H. Chiles, *Chairman;* Westinghouse Electric Corporation, Transformer Engineering Department, Sharon, Pa.

J. E. Clem	Schenectady, N. Y.
T. D. Gordy	Pittsfield, Mass.
D. L. Levine	Chicago, Ill.
A. J. Maslin	Sharon, Pa.
T. D. Reimers	New York, N. Y.
J. M. Towner	Baltimore, Md.

Hot Spot Temperature Rise of Class B Reactors Subcommittee

D. L. Levine, *Chairman;* Commonwealth Edison Company, 72 West Adams Street, Chicago 90, Ill.

F. H. Kiersted	Pittsfield, Mass.
L. E. Sauer	Sharon, Pa.

Permissible Maximum Oil Temperature in Service Subcommittee

M. H. Pratt, *Chairman;* Niagara Mohawk Power Corporation, 300 Erie Boulevard, Syracuse 2, N. Y.

J. G. Ford	Sharon, Pa.
J. R. Meador	Pittsfield, Mass.

Thermal Ratings as Affected by Reclosures Subcommittee

A. A. Johnson, *Chairman;* Westinghouse Electric Corporation, East Pittsburgh, Pa.

J. E. Clem	Schenectady, N. Y.
W. G. James	Sharon, Pa.
E. K. Kane	Pittsfield, Mass.
D. L. Levine	Chicago, Ill.
W. C. Sealey	Milwaukee, Wis.

Transmission and Distribution

Capacitor Subcommittee

F. V. Smith, *Chairman;* Sargent and Lundy, 140 South Dearborn Street, Chicago 3, Ill.

Glen Appleman	Allentown, Pa.
C. E. Baugh	San Francisco, Calif.
P. L. Bellaschi	Portland, Ore.
H. V. Dryer	So. Milwaukee, Wis.
K. B. Hapgood	Chattanooga, Tenn.
E. R. Hendrickson	Maywood, Ill.
R. E. Marbury	East Pittsburgh, Pa.
D. B. Masters	Jackson, Mich.
N. A. Miller	Chicago, Ill.
R. B. Miller	Davenport, Iowa
C. E. Parks	Indianapolis, Ind.
Leon Podolsky	North Adams, Mass.
F. F. Schaller, Jr.	Boston, Mass.
M. E. Scoville	Pittsfield, Mass.
E. C. Starr	Corvallis, Oreg.

Distribution Subcommittee

T. J. Brosnan, *Chairman;* Niagara Mohawk Power Corporation, 300 Electric Building, Buffalo, N. Y.

C. E. Baugh	San Francisco, Calif.
H. C. Bingham	Cleveland, Ohio
D. K. Blake	Schenectady, N. Y.
Bryce Brady	Oklahoma City, Okla.
Harold Cole	Detroit, Mich.
H. L. Davis	Philadelphia, Pa.
E. R. Hendrickson	Maywood, Ill.
J. B. Hodtum	Pittsburgh, Pa.
E. K. Huntington	Rochester, N. Y.
C. H. Kraft	St. Louis, Mo.
J. E. O'Brien	Washington, D. C.
E. W. Oesterreich	Pittsburgh, Pa.
J. S. Parsons	East Pittsburgh, Pa.
E. V. Sayles	Jackson, Mich.

General Systems Subcommittee

R. L. Witzke, *Chairman;* Industry Engineering Department, Westinghouse Electric Corporation, East Pittsburgh, Pa.

P. W. Blye	New York, N. Y.
R. W. Caswell	Chicago, Ill.
F. L. Code	Toronto, Ontario, Canada
O. A. Demuth	Portland, Oreg.
R. G. Hooke	Newark, N. J.
E. K. Huntington	Rochester, N. Y.
I. B. Johnson	Schenectady, N. Y.
A. A. Kroneberg	Los Angeles, Calif.
L. B. LeVesconte	Chicago, Ill.
L. M. Robertson	Denver, Colo.

Lightning and Insulator Subcommittee

J. T. Lusignan, *Chairman;* Ohio Brass Company, Engineering Department, Mansfield, Ohio

L. V. Bewley	Bethlehem, Pa.
H. N. Ekvall	Philadelphia, Pa.
H. A. Frey	Baltimore, Md.
I. W. Gross	New York, N. Y.
J. H. Hagenguth	Pittsfield, Mass.
E. L. Harder	East Pittsburgh, Pa.
W. W. Lewis	Schenectady, N. Y.
H. L. Rorden	Portland, Oreg.
S. K. Waldorf	Baltimore, Md.
E. R. Whitehead	Chicago, Ill.

Towers, Poles, and Conductors Subcommittee

A. E. Davison, *Chairman;* Hydro-Electric Power Commission of Ontario, 620 University Ave., Toronto, Ontario, Canada

N. K. Barr	Newark, Ohio
A. E. Beattie	Beaumont, Texas
H. W. Biskeborn	Newark, Ohio
A. A. Booker	Boston, Mass.
P. J. Croft	Toronto, Ontario, Canada
A. L. Duna	Worcester, Mass.
K. E. Hapgood	Chattanooga, Tenn.
E. L. Kanouse	Los Angeles, Calif.
W. H. Knutz	Hammond, Ind.
J. E. O'Brien	Washington, D. C.
A. A. Osipovich	Portland, Oreg.
F. W. Packer	Allentown, Pa.
T. F. Peterson	Cleveland, Ohio
J. A. Rawls	Richmond, Va.
L. M. Robertson	Denver, Colo.
A. S. Runciman	Montreal, Quebec, Canada
A. N. Shealy	Baltimore, Md.
E. J. Staubitz	Pittsburgh, Pa.
Joel Tompkins	Massena, N. Y.
F. Von Voigtlander	Jackson, Mich.
R. G. Yerke	Seward, Neb.

Science and Electronics Division

Basic Sciences

Applied Mathematics Subcommittee

M. G. Malti, *Chairman;* School of Electrical Engineering, Cornell University, Ithaca, N. Y.

Mathematicians

Garrett Birkhoff	Cambridge, Mass.
D. G. Bourgin	Urbana, Ill.
R. J. Duffin	Pittsburgh, Pa.
A. E. Hines	Pittsburgh, Pa.
Mark Kac	Ithaca, N. Y.
John Von Neumann	Princeton, N. J.
Harry Pollard	Ithaca, N. Y.
J. J. Stoker	New York, N. Y.
J. W. Tukey	Princeton, N. J.
D. V. Widder	Cambridge, Mass.
Norbert Wiener	Cambridge, Mass.
Max Woodbury	Princeton, N. J.

Electrical Engineers

P. L. Alger	Schenectady, N. Y.
Murray Gardner	Cambridge, Mass.
H. B. Hansteen	New York, N. Y.
E. W. Kimbark	Evanston, Ill.
Louis Pipes	Los Angeles, Calif.
Joseph Slepian	East Pittsburgh, Pa.
J. J. Smith	Schenectady, N. Y.
Harry Sohon	Philadelphia, Pa.

Electric Circuit Theory Subcommittee

H. J. Carlin, *Chairman;* Microwave Research Institute, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

J. G. Brainerd	Philadelphia, Pa.
R. L. Dietzold	Murray Hill, N. J.
M. J. Di Toro	Nutley, N. J.
A. B. Giordano	Brooklyn, N. Y.
E. A. Guillemin	Cambridge, Mass.
T. J. Higgins	Madison, Wis.
P. F. Ordung	New Haven, Conn.
W. O. Osbon	East Pittsburgh, Pa.
M. B. Reed	Urbana, Ill.

H. L. Tarpley	State College, Pa.
Ernst Weber	Brooklyn, N. Y.

Electrical Properties of Gases Subcommittee

T. B. Jones, *Chairman;* School of Electrical Engineering, Johns Hopkins University, Baltimore 18, Md.

J. D. Cobine	Schenectady, N. Y.
L. H. Fisher	New York, N. Y.
L. H. Germer	Murray Hill, N. J.
Joseph Slepian	East Pittsburgh, Pa.

Electrical Properties of Solids and Liquids Subcommittee

C. Bradner Brown, *Chairman;* Naval Gun Factory, United States Naval Ordnance Laboratory, White Oak, Md.

J. A. Becker	Murray Hill, N. J.
F. M. Clark	Schenectady, N. Y.
W. C. Dunlap	Schenectady, N. Y.
R. W. Engstrom	Lancaster, Pa.
K. Lark-Horovitz	Lafayette, Ind.
P. H. Miller, Jr.	Philadelphia, Pa.
Fred Seitz	Pittsburgh, Pa.
Lloyd Smith	Ithaca, N. Y.
A. von Hippel	Cambridge, Mass.
D. E. Wooldridge	Culver City, Calif.

Energy Sources Subcommittee

L. W. Matsch, *Chairman;* Illinois Institute of Technology, Department of Electrical Engineering, Chicago 16, Ill.

W. C. Brown	Point Mugu, Calif.
M. A. Garstens	Washington, D. C.
W. A. Lewis, Jr.	Chicago, Ill.
Walther Richter	Milwaukee, Wis.
J. J. Smith	Schenectady, N. Y.
B. R. Teare	Pittsburgh, Pa.
J. D. Tebo	New York, N. Y.
Milton Tenzer	Bradley Beach, N. J.

Magnetics Subcommittee

R. M. Bozorth, *Chairman;* Bell Telephone Laboratories, Inc., Murray Hill, N. J.

R. A. Chegwidden, *Secretary* Murray Hill, N. J.

F. G. Brockman	Irvington-on-Hudson, N. Y.
G. H. Cole	Middletown, Ohio
E. A. Gaugler	Silver Spring, Md.
J. E. Goldman	Pittsburgh, Pa.
W. Morrill	Pittsfield, Pa.
W. E. Ruder	Schenectady, N. Y.
C. W. Stoker	Pittsburgh, Pa.

Computing Devices

Analog Computers Subcommittee

E. L. Harder, *Chairman;* Industry Engineering Department 11-L, Westinghouse Electric Corporation, East Pittsburgh, Pa.

J. F. Calvert	Evanston, Ill.
A. C. Hall	Cambridge, Mass.
G. D. McCann	Pasadena, Calif.
V. Paschkis	New York, N. Y.
F. S. Rothe	Schenectady, N. Y.
H. G. Tremblay	Johnsville, Pa.

Digital Computers Subcommittee

S. N. Alexander, *Chairman;* National Bureau of Standards, Electronic Computers Section, Washington 25, D. C.

H. P. Kuehni	Schenectady, N. Y.
J. W. Mauchly	Philadelphia, Pa.
G. D. McCann	Pasadena, Calif.
J. C. McPherson	New York, N. Y.
P. L. Morton	Berkeley, Calif.
R. L. Snyder	Aberdeen Proving Ground, Md.

Computer Bibliography Subcommittee

W. H. MacWilliams, Jr., *Chairman;* Bell Telephone Laboratories, Inc., Whippany, N. J.

Electronic Power Converters

Administrative Subcommittee

Main Committee Officers:

C. C. Herskind, *Chairman;* General Electric Company, Power Electronics Division, Schenectady 5, N. Y.

W. N. Farquhar, *Vice-Chairman* Pittsburgh, Pa.
C. R. Marcum, *Secretary* East Pittsburgh, Pa.
Harold Winograd, *Preceding Chairman* Milwaukee, Wis.

Subcommittee Chairmen:
I. K. Dortort Philadelphia, Pa.
R. A. Nelson Pittsfield, Mass.
Waldo Porter Vancouver, Wash.
August Schmidt, Jr. Schenectady, N. Y.
J. C. Walter Camden, N. J.

Electronic Converter Application Subcommittee

W. N. Farquhar, *Chairman;* Aluminum Company of America, 801 Gulf Building, Pittsburgh 19, Pa.
C. E. Buterbaugh
E. H. Coxe, Jr. Baton Rouge, La.
F. W. Cramer Pittsburgh, Pa.
J. B. Donnelly Philadelphia, Pa.
N. W. Geist
W. E. Gutzwiller Milwaukee, Wis.
R. N. Hunter New York, N. Y.
Armin Leuthold Mt. Royal, Quebec, Canada
W. K. MacAdam New York, N. Y.
W. J. L. Rupprecht Midland, Mich.
S. L. Smith Philadelphia, Pa.
O. J. Swanson Gary, W. Va.
J. T. Thwaites Hamilton, Ontario, Canada
J. W. Ward Sylacauga, Ala.

Electronic Converter Circuits Subcommittee

I. K. Dortort, *Chairman;* Allis-Chalmers Manufacturing Company, Electrical Department, Milwaukee 1, Wis.
W. F. Bonner Clifton, N. J.
J. L. Boyer East Pittsburgh, Pa.
G. N. Hughes Alcoa, Tenn.
Otto Jensen Philadelphia, Pa.
G. F. Jones East Pittsburgh, Pa.
W. K. MacAdam New York, N. Y.
A. H. Mittag Schenectady, N. Y.
R. A. Nelson Pittsfield, Mass.
M. E. Reagan East Pittsburgh, Pa.
August Schmidt, Jr. Schenectady, N. Y.
C. H. Willis Princeton, N. J.

Papers and Speakers Subcommittee

August Schmidt, Jr., *Chairman;* General Electric Company, 1 River Road, Schenectady 5, N. Y.
J. B. Rice West Allis, Wis.
J. T. Thwaites Hamilton, Ontario, Canada
H. E. Zuvers Schenectady, N. Y.

Rectifier Transformers Subcommittee

R. A. Nelson, *Chairman;* General Electric Company, 100 Woodlawn Avenue, Pittsfield, Mass.
F. D. Kaiser Sharon, Pa.
A. J. Maslin Sharon, Pa.
W. C. Sealey Milwaukee, Wis.

Rectifying Devices Subcommittee

Harold Winograd, *Chairman;* Allis-Chalmers Manufacturing Company, Electrical Department, Milwaukee 1, Wis.
D. V. Edwards Newark, N. J.
D. E. Marshall Bloomfield, N. J.
August Schmidt, Jr. Schenectady, N. Y.
H. C. Steiner Schenectady, N. Y.

West Coast Subcommittee

Waldo Porter, *Chairman;* Aluminum Company of America, P. O. Box 120, Vancouver, Wash.
W. M. Allen Portland, Oreg.
E. D. Barcus Los Angeles, Calif.
E. S. Benson San Francisco, Calif.
H. L. Burris Pittsburg, Calif.
R. J. Corfield Garfield, Utah
J. H. Cox Sunnyvale, Calif.
R. H. Denyer Portland, Oreg.
A. G. Dickinson Trail, British Columbia, Canada
E. F. Donatic Ontario, Calif.
Alex. Dovjikov Portland, Oreg.
R. H. Duguid Los Angeles, Calif.
S. R. Durand Milwaukee, Wis.
L. E. Dye Los Angeles, Calif.
T. F. Hadwin Vancouver, British Columbia, Canada
D. R. Hoopes Salt Lake City, Utah
J. V. Kresser San Francisco, Calif.
C. A. Langloid Portland, Oreg.
H. F. Lickey Pullman, Wash.
M. McCoy Portland, Oreg.
A. L. Munn San Leandro, Calif.
S. J. Pope Spokane, Wash.
H. H. Skilling Stanford, Calif.
E. C. Starr Corvallis, Oreg.
H. V. Strandberg Seattle, Wash.
J. R. Tenney Geneva, Utah

Hot-Cathode Power Converter Subcommittee

J. C. Walter, *Chairman;* Radio Corporation of America, Camden, N. J.
R. W. Barker Pittsfield, Mass.
W. H. Bixby Detroit, Mich.
H. R. Butler Newark, N. J.
F. W. Cramer Pittsburgh, Pa.
D. V. Edwards Newark, N. J.
C. E. Hamann Lynn, Mass.
J. F. Harris Newark, N. J.
E. W. Hutton Schenectady, N. Y.
W. E. Large East Pittsburgh, Pa.
F. G. Logan St. Louis, Mo.
E. J. Rathsack Milwaukee, Wis.
F. M. Rives Schenectady, N. Y.
W. C. Rudd Larchmont, N. Y.
J. W. Sanborn Camden, N. J.
D. H. Smith Schenectady, N. Y.
H. C. Steiner Schenectady, N. Y.
H. L. Thorson Schenectady, N. Y.
D. E. Trucksess New York, N. Y.

Electronics

Electron Tubes Subcommittee

H. C. Steiner, *Chairman;* Electronics Department, I. & T. Tube Division, General Electric Company, Schenectady 5, N. Y.
A. Y. Bentley Passaic, N. J.
W. R. Clark Philadelphia, Pa.
F. W. Cramer Pittsburgh, Pa.
D. V. Edwards Newark, N. J.
A. V. Glover Lancaster, Pa.
R. E. Graham Kew Gardens, N. Y.
William Happe, Jr. Clifton, N. J.
L. B. Headrick Lancaster, Pa.
Scott Helt Passaic, N. J.
J. H. Hutchings Geneva, Ill.
K. S. Koon Endicott, N. Y.
O. W. Livingston Schenectady, N. Y.
C. R. Marcum East Pittsburgh, Pa.
D. E. Marshall Bloomfield, N. J.
August Schmidt, Jr. Schenectady, N. Y.
Thomas Spooner East Pittsburgh, Pa.
J. T. Thwaites Hamilton, Ontario, Canada
Simeon Weston Brooklyn, N. Y.
W. C. White Schenectady, N. Y.
C. H. Willis Princeton, N. J.
Harold Winograd Milwaukee, Wis.

X-Ray Tubes, Apparatus and Applications Subcommittee

Scott W. Smith, *Chairman;* X-Ray Section, National Bureau of Standards, Washington 25, D. C.
Z. J. Atlee Chicago, Ill.
Arthur Klinchermann Chicago, Ill.
Joseph Lempert Bloomfield, N. J.
G. E. Maxim Cleveland, Ohio
T. H. Rogers Springdale, Conn.
David Sussin Covington, Ky.
Robert F. Wilson Milwaukee, Wis.

Electrostatic Processes Subcommittee

G. W. Hewitt, *Chairman;* Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.
J. O. Amstuz Troy, N. Y.
J. E. Coolidge, Jr. State College, Pa.
E. P. Miller Indianapolis, Ind.
H. V. Nelson Schenectady, N. Y.
S. R. Orem, Jr. Greenwich, Conn.
G. W. Penney Pittsburgh, Pa.
E. R. Thomas New York, N. Y.
J. B. Thomas Fort Worth, Texas
H. J. White Bound Brook, N. J.

High Frequency Conductors, Cables, and Connectors Subcommittee

G. J. Crowdes, *Chairman;* Simplex Wire and Cable Company, 79 Sidney Street, Cambridge 39, Mass.
W. R. Dohan Camden, N. J.
E. W. Greenfield Hastings-on-Hudson, N. Y.
J. D. Heibel Erie, Pa.
B. A. Jackson New York, N. Y.
W. J. King Murray Hill, N. J.
H. B. Slade Passaic, N. J.
W. R. Thurston Cambridge, Mass.

Liaison with Nucleonics Subcommittee

G. A. Morton, *Chairman;* R. C. A. Laboratories, Princeton, N. J.

Electronic Aids to Navigation Subcommittee

H. R. Mimno, *Chairman,* Cruft Laboratory, Harvard University, Cambridge 38, Mass.

Electronic Aids to Geophysics Subcommittee

L. G. Cowles, *Chairman;* The Superior Oil Company, Houston, Texas

Infrared Applications Subcommittee

A. H. Canada, *Chairman;* General Engineering and Consulting Laboratory, General Electric Company, Schenectady 5, N. Y.
A. R. Dennett Newport, R. I.
William A. Dynes Dayton, Ohio
W. G. Fastie Philadelphia, Pa.
B. J. Goldfarb Dayton, Ohio
E. D. Wilson East Pittsburgh, Pa.
C. S. Woodside Washington, D. C.

Electronic Methods in Food and Biological Processing Subcommittee

T. H. Morrin, *Chairman;* Department of Electrical Engineering, Stanford Research Institute, Stanford, Calif.

Magnetic Amplifiers Subcommittee

E. L. Harder, *Chairman;* Westinghouse Electric Corporation, East Pittsburgh, Pa.
E. V. Weir, *Secretary* Silver Spring, Md.
A. O. Black Butler, Pa.
L. W. Buechler St. Louis, Mo.
W. J. Dornhoefer St. Louis, Mo.
L. A. Finzi Pittsburgh, Pa.
A. S. Fitzgerald San Francisco, Calif.
W. A. Geyger Silver Spring, Md.
A. B. Haines Murray Hill, N. J.
J. E. Hart Washington, D. C.
A. D. Hitt, Jr. Washington, D. C.
W. C. Johnson Princeton, N. J.
R. E. Morgan Schenectady, N. Y.
H. B. Rex Washington, D. C.
P. L. Schmidt East Pittsburgh, Pa.
R. W. Wolke Schenectady, N. Y.
D. W. VerPlanck Pittsburgh, Pa.

Working Groups:

(1) Definitions
W. J. Dornhoefer, *Sponsor* St. Louis, Mo.
E. L. Harder East Pittsburgh, Pa.
L. A. Finzi Pittsburgh, Pa.
A. B. Haines Murray Hill, N. J.
E. B. McDowell Schenectady, N. Y.
E. V. Weir Silver Spring, Md.

(2) Speed of Response, Figure of Merit
L. A. Finzi, *Sponsor* Pittsburgh, Pa.
E. L. Harder East Pittsburgh, Pa.
W. J. Dornhoefer St. Louis, Mo.
W. C. Johnson Princeton, N. J.
R. E. Morgan Schenectady, N. Y.
H. B. Rex Washington, D. C.
D. W. VerPlanck Pittsburgh, Pa.
E. V. Weir Silver Spring, Md.

(3) Ratings
R. W. Wolke, *Sponsor* Schenectady, N. Y.
W. J. Dornhoefer St. Louis, Mo.
L. A. Finzi Pittsburgh, Pa.
E. L. Harder East Pittsburgh, Pa.
J. E. Hart Washington, D. C.
R. E. Morgan Schenectady, N. Y.

Electronic Applications of Semiconductor Devices Subcommittee

C. Bradner Brown, *Chairman;* Research Engineering, Naval Ordnance Laboratory, White Oak, Md.
Harold Goldberg Washington, D. C.
J. R. Hyneman New York, N. Y.
G. D. O'Neill Kew Gardens, N. Y.

Liaison with Electronic Heating Subcommittee

T. P. Kinn, *Chairman;* Electronics and X-Ray Division, Westinghouse Electric Corporation, 2519 Wilkens Avenue, Baltimore 3, Md.
R. M. Baker Baltimore, Md.
W. C. Rudd Larchmont, N. Y.

Electronic Systems Engineering Subcommittee

H. L. Flowers, *Chairman;* Aerophysics Department, Goodyear Aircraft Corporation, Akron 15, Ohio
(Personnel to be selected)

Electronic Standards and Definitions Subcommittee

O. W. Pike, *Chairman;* Vacuum Tube Engineering Department, General Electric Company, Schenectady 5, N. Y.

Liaison with IRE Subcommittee

R. S. Burnap, *Chairman;* Radio Corporation of America, R. C. A. Victor Division, Harrison, N. J.

Liaison with JETEC Subcommittee

O. W. Pike, *Chairman;* Vacuum Tube Engineering Department, General Electric Company, Schenectady 5, N. Y.

Education in Electronics Subcommittee

J. D. Ryder, *Chairman;* Department of Electrical Engineering, University of Illinois, Urbana, Ill.
E. M. Boone Columbus, Ohio
M. A. Honnell Atlanta, Ga.
B. K. Northrop Ithaca, N. Y.
A. J. Quigley Notre Dame, Ind.
J. T. Thwaites Hamilton, Ont., Canada
D. G. Wilson Lawrence, Kansas

Papers Review Subcommittee

W. C. White, *Chairman;* General Electric Research Laboratory, The Knolls, Schenectady, N. Y.
G. M. K. Baker Princeton, N. J.
W. R. Clark Philadelphia, Pa.
H. F. Dart Bloomfield, N. J.
Rudolf Feldt Clifton, N. J.
R. E. Graham Kew Gardens, N. Y.
S. B. Ingram New York, N. Y.
L. A. Kilgore East Pittsburgh, Pa.
H. L. Palmer Schenectady, N. Y.
H. C. Steiner Schenectady, N. Y.
Dayton Ulrey Lancaster, Pa.
Harold Winograd Milwaukee, Wis.

Instruments and Measurements

Organization Subcommittee

T. S. Gray, *Chairman;* Massachusetts Institute of Technology, Cambridge 39, Mass.
C. F. Savage, *Secretary* Lynn, Mass.
E. I. Green Murray Hill, N. J.
H. C. Koenig New York, N. Y.
J. G. Reid, Jr. Washington, D. C.

Definitions Subcommittee

C. L. Dawes, *Chairman;* Harvard University, Cambridge 39, Mass.
J. E. Clem Schenectady, N. Y.
A. B. Craig Boston, Mass.
H. C. Dickinson Lynn, Mass.
W. N. Goodwin, Jr. Newark, N. J.
Everett S. Lee Schenectady, N. Y.
B. E. Lenehan Newark, N. J.
F. B. Silsbee Washington, D. C.

Electrical Tests on Dielectrics in the Field Subcommittee

F. C. Doble, *Chairman;* Doble Engineering Company, Box 344, Belmont 78, Mass.
W. G. Amey Philadelphia, Pa.
D. L. Brown Portland, Oreg.
A. L. Brownlee Chicago, Ill.
E. B. Curdts Philadelphia, Pa.
C. L. Dawes Cambridge, Mass.
W. F. Dunkle Hazleton, Pa.
I. G. Easton Cambridge, Mass.
W. N. Eddy Cambridge, Mass.
J. G. Ford Sharon, Pa.
I. W. Gross New York, N. Y.

Everett S. Lee   Schenectady, N. Y.
W. N. Lindblad   Emeryville, Calif.
G. M. L. Sommerman   Evanston, Ill.
E. R. Thomas   New York, N. Y.
L. Wetherill   Pittsfield, Mass.

High-Frequency Measurements Subcommittee

Harold Lyons, *Chairman;* National Bureau of Standards, Microwave Measurement Laboratory, Washington, D. C.
S. L. Bailey   Washington, D. C.
E. P. Felch, Jr.   Murray Hill, N. J.
F. Hamburger, Jr.   Baltimore, Md.
H. R. Meahl   Schenectady, N. Y.
H. A. Wheeler   Great Neck, N. Y.
A. J. Wing, Jr.   Evanston, Ill.

Industrial Spectroscopy Subcommittee

J. H. Enns, *Chairman;* Randall Laboratory, University of Michigan, Ann Arbor, Michigan
H. M. Bedell   Cleveland, Ohio
G. D. Butler   New York, N. Y.
D. K. Coles   East Pittsburgh, Pa.
C. H. Corliss   Washington, D. C.
H. M. Crosswhite   Baltimore, Md.
W. G. Fastie   Philadelphia, Pa.
W. D. Hershberger   Berkeley, Calif.
E. K. Jaycox   Murray Hill, N. J.
L. W. McNair   Wood River, Ill.
John Sterner   Cambridge, Mass.
J. Sherman   Philadelphia, Pa.
Van Zandt Williams   Glenbrook, Conn.

Marking of Varmeters and Related Instruments Subcommittee

A. B. Craig, *Chairman;* Boston Edison Company, 39 Boylston Street, Boston 12, Mass.
A. L. Brownlee   Chicago, Ill.
A. L. Carvill   Lynn, Mass
W. G. Knickerbocker   Detroit, Mich.
A. E. Knowlton   New York, N. Y.
F. A. Redding   Los Angeles, Calif.
F. B. Silsbee   Washington, D. C.
H. B. Smith   Buffalo, N. Y.

Master Test Code for Power Measurements Subcommittee

C. J. Zeller, *Chairman;* Consolidated Edison Company of New York, Inc., 708—1st Avenue, New York 17, N. Y.
W. G. Knickerbocker   Detroit, Mich.
H. C. Koenig   New York, N. Y.
B. E. Lenehan   Newark, N. J.
L. W. Matsch   Chicago, Ill.
J. H. Miller   Newark, N. J.
C. F. Savage, Jr.   West Lynn, Mass.
Harry Sohon   Philadelphia, Pa.
L. N. Stone   Corvallis, Oreg.

Master Test Code for Temperature Measurements Subcommittee

L. A. Burckmyer, Jr., *Chairman;* Cornell University, Ithaca, New York
P. A. Borden   Waterbury, Conn.
E. D. Doyle   Philadelphia, Pa.
J. L. Fuller   Cleveland, Ohio
W. R. Hough   Cleveland, Ohio
A. K. Joecks   New York, N. Y.
S. S. Stack   Schenectady, N. Y.

Revision of Standard Number 4 (Measurement of Test Voltage in Dielectric Tests) Subcommittee

J. T. Lusignan, Jr., *Chairman;* Engineering Department, Ohio Brass Company, Mansfield, Ohio
P. L. Bellaschi   Portland, Oreg.
A. L. Brownlee   Chicago, Ill.
J. S. Carroll   Stanford University, Calif.
J. J. Clark   East Pittsburgh, Pa.
E. W. Davis   Cambridge, Mass.
C. M. Foust   Schenectady, N. Y.
H. A. Frey   Baltimore, Md.
I. W. Gross   New York, N. Y.
J. H. Hagenguth   Pittsfield, Mass.
W. B. Kouwenhoven   Baltimore, Md.
R. L. Lapp   LeRoy, N. Y.
W. W. Lewis   Schenectady, N. Y.
M. Newman   Minneapolis, Minn.
J. H. Park   Washington, D. C.
W. C. Sealey   Milwaukee, Wis.
W. T. Smith   Arlington, Va.
R. W. Sorensen   Pasadena, Calif.
W. L. Teague   Sharon, Pa.
S. W. Zimmerman   Ithaca, N. Y.

Watt-hour Meters Subcommittee

C. F. Savage, Jr., *Chairman;* General Electric Company, 40 Federal Street, West Lynn, Mass.
H. A. Brown   Rochester, N. Y.
G. N. Burkhart, Jr.   Lafayette, Ind.
D. T. Canfield   Lafayette, Ind.
A. B. Craig   Boston, Mass.
F. C. Holtz   Springfield, Ill.
W. G. Knickerbocker   Detroit, Mich.
H. C. Koenig   New York, N. Y.
B. E. Lenehan   Newark, N. J.
W. N. Lindblad   Emeryville, Calif.
F. H. Rogers   Baltimore, Md.
K. M. Stevens   Alhambra, Calif.
M. B. Stout   Ann Arbor, Mich.
J. M. Vanderleck   Toronto, Ontario, Canada

Co-operation with Instrument Society of America Subcommittee

A. J. Hornfeck, *Chairman;* Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio
J. J. Bowen   Buffalo, N. Y.
C. J. Brumbaugh   Hamburg, N. Y.
F. C. Rushing   Buffalo, N. Y.

Metallic Rectifiers

Technical Information Subcommittee

C. E. Hamann, *Chairman;* Rectifier Division, General Electric Company, 930 Western Avenue, Lynn 3, Mass.
M. E. Gamble   Indianapolis, Ind.
L. K. Hedding   Pittsburgh, Pa.
J. L. Wagner   Endicott, N. Y.

Miniature Rectifiers Subcommittee

P. G. Cobb, *Chairman;* Weston Electrical Instrument Corporation, 614 Frelinghuysen Avenue, Newark 5, N. J.

Definitions Subcommittee

D. E. Trucksess, *Chairman;* Bell Telephone Laboratories, Inc., 463 West Street, New York 14, N. Y.
W. F. Bonner   Clifton, N. J.
C. W. Hansell   Rocky Point, L. I., N. Y.

Bibliography Subcommittee

E. A. Harty, *Chairman;* Rectifier Engineering Division, General Electric Company, River Works, West Lynn 3, Mass.

Test Code Subcommittee

W. F. Bonner, *Chairman;* Selenium-Intelin Division, Federal Telephone and Radio Corporation, 100 Kingsland Avenue, Clifton, N. J.
J. T. Cataldo   Fort Monmouth, N. J.
K. S. Geiges   New York, N. Y.

Patents Subcommittee

Glen Ramsey, *Chairman;* Fansteel Metallurgical Corporation, Rectifier Division, North Chicago, Ill.

Papers and Meetings Subcommittee

L. W. Burton, *Chairman;* General Electric Company, River Works, 920 Western Avenue, Lynn, Mass.
E. A. Groeteke   St. Louis, Mo.
Glen Ramsey   North Chicago, Ill.

Nucleonics

Isotopic Tracers Subcommittee

R. E. Watson, *Chairman;* Research Department, Leeds and Northrup Company, 4901 Stenton Avenue, Philadelphia 44, Pa.
(Personnel to be selected)

Nuclear Theory Subcommittee

P. N. Ross, *Chairman;* Atomic Power Division, Westinghouse Electric Corporation, Bettis Field, P. O. Box 1468, Pittsburgh 30, Pa.

Nuclear Machines Subcommittee

J. G. Hutton, *Chairman;* General Engineering and Consulting Laboratory, General Electric Company, Schenectady 5, N. Y.
(Personnel to be selected)

Therapeutics

No subcommittees

Joint Subcommittees

Joint Subcommittee on Applications of Probability Methods to Power-System Problems (Joint with Power Generation and System Engineering Committees)

G. Calabrese, *Chairman;* Electrical Engineering Department, New York University, University Heights, New York 53, N. Y.
W. R. Blakely   Toronto, Ontario, Canada
V. M. Cook   New York, N. Y.
Howard Duryea   Birmingham, Ala.
R. G. Hooke   Newark, N. J.
H. A. Lott   Los Angeles, Calif.
F. J. Leerburger   New York, N. Y.
W. J. Lyman   Pittsburgh, Pa.
Bela Mohr   Oklahoma City, Okla.
H. W. Phillips   Philadelphia, Pa.
H. B. Smith   Buffalo, N. Y.
V. A. Thiemann   New York, N. Y.
C. W. Watchorn   Baltimore, Md.

Joint Subcommittee on Electrical Aids to Medicine (Joint with Electronics, Instruments and Measurements, and Therapeutics Committees)

Kendrick Hare, *Chairman;* Childrens' Hospital, 219 Bryant Street, Buffalo 9, N. Y.
G. W. Dunlap   Schenectady, N. Y.
W. A. Geohegan   New York, N. Y.
Harry Grundfest   New York, N. Y.
J. P. Hervey   Baltimore, Md.
R. S. Mackay   Berkeley 4, Calif.
G. A. Morton   Princeton, N. J.
J. G. Reid, Jr.   Washington, D. C.
S. W. Smith   Washington, D. C.
C. A. Tobias   Berkeley, Calif.
S. R. Warren, Jr.   Philadelphia, Pa.
A. M. Zarem   Los Angeles, Calif.

Joint Subcommittee on Electronic Instruments (Joint with Electronics and Instruments and Measurements Committees)

Rudolf Feldt, *Chairman;* Allen B. DuMont Laboratories, Inc., 1000 Main Avenue, Clifton, N. J.
W. H. Tidd, *Vice-Chairman*   New York, N. Y.
P. K. McElroy, *Secretary*   Cambridge, Mass.
M. J. Ackerman   Camden, N. J.
G. E. Beggs   Philadelphia, Pa.
Cledo Brunetti   Stanford, Calif.
C. C. Chambers   Philadelphia, Pa.
H. F. Dart   Bloomfield, N. J.
G. W. Downs   Pasadena, Calif.
G. V. Eltgroth   Philadelphia, Pa.
E. R. Haberland   Silver Spring, Md.
C. E. Hastings   Hampton, Va.
C. M. Hathaway   Denver, Colo.
D. M. Hill   Boonton, N. J.
G. B. Hoadley   Raleigh, N. C.
E. J. Isbister   Great Neck, N. Y.
W. J. Jones   Belmar, N. J.
N. W. Matthews   Washington, D. C.
H. R. Meahl   Schenectady, N. Y.
Edmund Osterland   Boonton, N. J.
David Packard   Palo Alto, Calif.
T. B. Perkins   Harrison, N. J.
J. G. Reid, Jr.   Washington, D. C.
E. R. Thomas   New York, N. Y.
J. T. Thwaites   Hamilton, Ontario, Canada
Howard Vollum   Portland, Oreg.
A. H. Waynick   State College, Pa.
W. P. Wills   Philadelphia, Pa.

Joint Subcommittee on Nucleonics Instruments (Joint with Nucleonics and Instruments and Measurements Committees)

G. A. Morton, *Chairman;* Radio Corporation of America, R.C.A. Laboratories Division, Princeton, N. J.
(Personnel to be selected)

Joint Subcommittee on Standard Frequency Bands and Designations

G. B. Ransom, *Chairman;* American Telephone and Telegraph Company, 32 Avenue of the Americas, New York 13, N. Y.
I. G. Easton   Cambridge, Mass.
T. P. Kinn   Baltimore, Md.
J. E. McCormack   New York, N. Y.
F. B. Silsbee   Washington, D. C.

Joint Subcommittee on Telemetering (Joint with Instruments and Measurements and Substations Committees)

W. J. Mayo-Wells, *Chairman;* Applied Physics Laboratory, The Johns Hopkins University, 8621 Georgia Avenue, Silver Spring 18, Md.
J. L. McKee, *Secretary*   New York, N. Y.
J. L. Blackburn   Newark, N. J.
P. A. Borden   Waterbury, Conn.
M. A. Bostwick   Portland, Oreg.
J. F. Brinster   Princeton, N. J.
E. C. Brown   Hartford, Conn.
W. A. Derr   East Pittsburgh, Pa.
C. K. Duff   Toronto, Ontario, Canada
A. J. Hornfeck   Cleveland, Ohio
G. S. Lunge   Schenectady, N. Y.
E. E. Lynch   West Lynn, Mass.
W. E. Phillips   Philadelphia, Pa.
Merle Robison   Toledo, Ohio
G. M. Thynell   Waterbury, Conn.
J. H. Vivian   Los Angeles, Calif.
B. G. Walker   Minneapolis, Minn.
C. E. Winegartner   Cleveland, Ohio

Working Group on Telemetering Terms:
W. J. Mayo-Wells, *Chairman*   Silver Spring, Md.
G. R. Anderson   North Hollywood, Calif.
J. L. Blackburn   Newark, N. J.
A. T. Gruer   Albuquerque, N. M.
M. V. Kiebert   Philadelphia, Pa.
R. L. Harding   South Bend, Ind.
F. Lehan   Pasadena, Calif.
E. E. Lynch   West Lynn, Mass.
M. G. Pawley   Washington, D. C.
J. M. Pearce   Baltimore, Md.
W. E. Phillips   Philadelphia, Pa.
G. M. Thynell   Waterbury, Conn.
F. L. Verwiebe   Silver Spring, Md.
G. F. C. Weedon   Toronto, Ontario, Canada
W. A. Wildhack   Washington, D. C.

Joint Subcommittee on Carbon Brushes (Joint AIEE Technical Committees on Air Transportation and Rotating Machinery, and in Co-operation with NEMA on Codes)

T. M. Linville, *Chairman;* General Electric Company, 1 River Road, Schenectady 5, N. Y.
W. H. Austry   St. Marys, Pa.
R. J. Blais   New York, N. Y.
H. R. Brown   Seattle, Wash.
W. E. Clancy   St. Marys, Pa.
J. V. Dobson   St. Marys, Pa.
H. M. Elsey   East Pittsburgh, Pa.
D. E. Fritz   Cleveland, Ohio
L. A. Heath   Long Island City, N. Y.
B. C. Henry   Ironton, Ohio
C. J. Herman   Fort Wayne, Ind.
V. P. Hessler   Urbana, Ill.
L. H. Hildebrandt   Dayton, Ohio
H. T. Hulbert   St. Marys, Pa.
R. E. Klokow   Lima, Ohio
E. A. Lapham   Long Island City, N. Y.
K. Lugosch   Johnsville, Pa.
C. Lynn   East Pittsburgh, Pa.
I. H. Manfredo   Brooklyn, N. Y.
M. S. May   St. Marys, Pa.
H. F. Mitchel   Saginaw, Mich.
L. C. Novak   West Lynn, Mass.
H. R. Partridge   Boonton, N. J.
D. Ramadanoff   Cleveland, Ohio
O. C. Rutledge   Schenectady, N. Y.
S. D. Summers   Washington, D. C.
F. R. Terrant   Cleveland, Ohio
A. L. VanEmden   Washington, D. C.
W. W. Walker   Yonkers, N. Y.

Fulbright Opportunities Offered for Academic Year 1951-52

Approximately 300 awards for United States citizens to serve as visiting lecturers or to undertake research abroad during the academic year 1951–52 have been announced by the Department of State under the provisions of Public Law 584 (79th Congress), the Fulbright Act.

Many of the awards are open to college and university professors, research scholars, and specialists in engineering and related fields. Countries now participating in the program are Australia, Belgium-Luxembourg (including the Belgian Congo), Burma, Egypt, France, Greece, India, Iran, Italy, Netherlands, New Zealand, Norway, the Philippines, Turkey, and the United Kingdom, including the British Colonial Dependencies.

In addition to the large number of awards offered without specification of subject or sponsoring institution, attention is called to the following specific opportunities in engineering and related fields at certain designated institutions abroad:

Electronics. A visiting lecturer in applied science with specialization in electronics would be especially welcomed in the Belgian universities. A candidate selected in this field would be expected to lecture at the principal universities in Belgium, thus giving more scholars a chance to benefit from his presence. Lectures may be given in English, but a knowledge of French or Flemish would be helpful. Facilities will also be available for independent research.

High Frequency and Wave Guides. A specialist in this field has been requested by the faculty of engineering at Fouad I University in Cairo, Egypt.

Electrical Engineering. Requests have been made by the Polytechnic Institutes of Turin and Milan, Italy, and the Instituto Nazionale di Electrotechnica Galileo Ferraira (a highly specialized graduate school in Turin) for visiting lecturers in electrical engineering with particular emphasis placed upon electronics, microwaves, and radar.

Supersonics. Delft Technical Institute, the only institution of its kind in the Netherlands on the university level, is keenly aware of American leadership in the field of supersonics and would welcome a visiting lecturer in this field who would devote himself to the problems of shock waves and supersonic velocities.

Measurement Methods in Technical Physics. The Institute of Technology, Trondheim, is the center of technological instruction and research in Norway. The institute would especially welcome a visiting lecturer from the United States who has specialized in experimental stress analysis such as wire resistance, strain gauges, stress coat, photoelasticity, ultrasound, and in methods of measuring vibration, fatigue, creep, residual stresses, biaxial and triaxial stresses, and so forth.

Gas and Steam Turbines, Airplane Design, or Production Control. The Institute of Technology, Trondheim, lists these subjects as alternate specialties in which a visiting lecturer would be welcomed.

Most of the awards in the United Kingdom are offered without designation of subject or sponsoring institution. Opportunities are numerous, however, for lecturing or research in engineering in the British universities, although the number of awards that can be made in any one field are necessarily limited. The United States Educational Commission for the United Kingdom reports that an interest in receiving visiting lecturers and research scholars in engineering has been expressed by the following universities or university colleges: Birmingham (electrical engineering—especially in the field of automatic control, both theoretical and industrial metallurgy, mechanical engineering); Cambridge; Edinburgh (dynamics, especially mechanical vibration and sound); Liverpool (electrical engineering and electronics, heat transmission, and steam power); Leeds (mineral dressing); London (electrical engineering, reinforced concrete); Manchester (soil mechanics); Nottingham (mine ventilation); Sheffield (metallurgy and mining). Opportunities are also available in numerous British technical institutes.

Since it is desirable that grantees be distributed widely throughout the British university system, applications with a view to attachment at universities other than Cambridge, Oxford, and London are especially encouraged.

Most of the countries participating in the Fulbright program—especially France, Italy, and the United Kingdom—provide a number of awards without designating the subject or receiving institution. University teachers or postdoctoral scholars in the field of engineering and related fields should not hesitate to apply for undesignated awards, especially for research, in countries in which they are interested.

No award will be made for teaching or research in more than one country in any one year and only one application may be filed each year. Applicants may indicate an alternate country, however, if the proposed activity can be satisfactorily completed in more than one country. In case he cannot be accommodated in the program of the country of his first choice, he may be considered for the alternate country named.

The closing date for filing applications for awards for lecturing and research for the academic year 1951–52 is October 15, 1950. Requests for application forms and for further information concerning opportunities for visiting lecturers, research scholars, and specialists should be addressed to the Committee on International Exchange of Persons, Conference Board of Associated Research Councils, 2101 Constitution Avenue, Washington 25, D. C.

Labor and Management Plan Co-operation for Safety

The President's Conference on Industrial Safety, composed of leaders of American business, labor, insurance, educational, and private safety organizations, is dedicated to the saving of human lives, money, and production in industry. As a means of furthering this objective, the present Conference Committee on Labor-Management Cooperation for Safety has recommended the following principles:

1. The term "labor-management cooperation for safety" is construed as evidence of actual co-operation, regardless of method, between the employer and the employees in a particular establishment wherein, as a result of such co-operation, accidents have been reduced or the accident experience maintained at a low level.

The following are recognized as the generally existing patterns of management and labor co-operation and/or participation in safety:

(*a*). A joint safety committee or safety council comprising representatives of the company and the union, whether or not such

Future Meetings of Other Societies

American Society of Mechanical Engineers. 19th National Exposition of Power and Mechanical Engineering. November 27–December 2, 1950, Grand Central Palace, New York, N. Y.

American Standards Association. Annual Meeting. November 27–29, 1950, Waldorf-Astoria Hotel, New York, N. Y.

American Welding Society. 31st Annual Meeting. October 22–27, 1950, Hotel Sherman, Chicago, Ill.

Audio Engineering Society. 2d Audio Fair. October 26–28, 1950, Hotel New Yorker, New York, N. Y.

Engineers' Council for Professional Development. 18th Annual Meeting. October 20–21, 1950, Tudor Arms Hotel, Cleveland, Ohio.

Industrial Management Society. 14th Annual National Time, Motion, and Management Clinic. November 2–3, 1950, Sheraton Hotel, Chicago, Ill.

National Academy of Sciences. October 9–11, 1950, General Electric Research Laboratories, Schenectady, N. Y.

National Conference on Industrial Hydraulics. Sixth Annual Conference. October 18–19, 1950, Sherman Hotel, Chicago, Ill.

National Electrical Manufacturers Association. November 13–16, 1950, Chalfonte-Haddon Hall, Atlantic City, N. J.

National Research Council. 1950 Conference on Electrical Insulation. November 1–3, 1950, Pocono Manor Inn, Pocono Manor, Pa.

National Safety Congress and Exposition. October 16–20, 1950, Stevens, Morrison, and Congress Hotels, Chicago, Ill.

Radio Fall Meeting. Annual meeting of radio engineers, sponsored by the Institute of Radio Engineers and the Radio-Television Manufacturers Association's Engineering Department. October 30–November 1, 1950, Hotel Syracuse, Syracuse, N. Y.

Society of Automotive Engineers. Transportation Meeting. October 16–18, 1950, Hotel Statler, New York, N. Y.

Society of the Plastics Industry. Annual National Conference. October 18–20, 1950, New Ocean House, Swampscott, Mass.

arrangement is specifically provided for in the agreement.

(*b*). A unionized company or plant in which the safety program is organized and conducted by management with worker co-operation and/or participation without the use of a joint union management committee.

(*c*). A nonunion plant with worker co-operation and/or participation in the safety program.

2. The industrial accident problem can be solved only by full co-operation between the employer and employee.

3. There must be genuine participation on the part of all levels of management and employees in building and stimulating the safety efforts of the entire organization. This will produce understanding, pride in results, and an appreciation of the sincerity and good faith of each party to the program.

Based on these premises, the following principles are fundamental:

1. Safety primarily is the legal and moral obligation of the employer. The employer must have a sincere and continuing interest in providing for the safety of employees. This interest is demonstrated by:

(*a*). The initiation of a sound safety program with the policies, procedures, and staff necessary to make it effective.

(*b*). The provision of safe working conditions, machinery, equipment, personal safety, protective devices, and apparel where necessary.

(*c*). The development of effective training programs for supervisors and employees.

(*d*). The encouragement of employee interest and participation by making available channels through which employees may offer suggestions, advice, and recommendations for the improvement of safety.

Management must have the authority necessary to carry out its responsibility. No steps should be taken which create confusion and uncertainty as to management's responsibility and authority.

2. Co-operation in the safety program is the moral obligation of each individual employee. This is demonstrated by:

(*a*). Working safely at his job.

(*b*). Having regard at all times for the safety of fellow employees.

(*c*). Using his knowledge and influence to prevent accidents.

(*d*). Calling attention to unsafe conditions.

(*e*). Contributing his ideas, suggestions, and recommendations for the improvement of safety.

3. In unionized plants, the welfare of the employees places upon the labor union a moral obligation to co-operate in accident prevention, within the framework of its agreed-upon participation. This is demonstrated by:

(*a*). Taking its agreed part in the safety program in the plant.

(*b*). Using its influence in encouraging the employees it represents to work safely.

(*c*). Promoting accident prevention through its publications, union meetings, and educational courses, with emphasis not only upon plant safety but also with due regard to safety in the home, on the highway, and in other activities outside the plant.

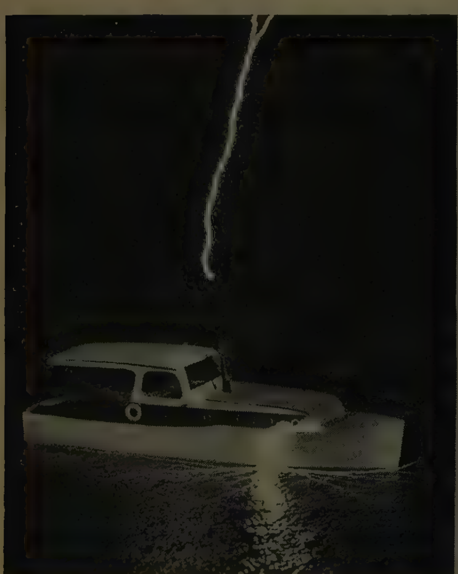
Copper Wire Protects Small Boats From Danger of Lightning

Lightning statistics say that a 30-foot pleasure boat will be struck by lightning once in 30 years on an average, but J. M. Wallace of the Westinghouse Electric Corporation has shown how a few feet of copper wire and several hours of work will eliminate the gamble and fully protect the craft from danger. A series of demonstrations conducted in the company's High-Voltage Laboratory at Trafford, Pa., where a 3-foot model of Mr. Wallace's own boat was subjected to repeated strokes of 3,000,000-volt man-made lightning, shows that the simple precautions he suggests will divert lightning currents harmlessly into the water with no injuries to boat or occupants.

Small boats will be protected from lightning damage if a copper wire is run from a sufficiently high point on the boat such as a mast to any metal object that is in contact with the water such as a centerboard or rudder or engine that is in contact with the water through the propeller shaft. Lightning will follow the wire and be conducted safely into the water.

Sailboats generally have a mast high enough to offer a sufficient "cone of protection," according to Mr. Wallace. Anything within this cone, whose base has a diameter equal to the height of the mast, will be protected by the mast. A length of aluminum tubing attached to shorter masts will give the necessary height. Since most motorboats have their masts located in the forward part of the boat, it is wise to ground the stern light as well as the mast. In this way, the boat will be guarded by two overlapping cones of protection. In the tests at Trafford, it was discovered that approximately one out of every 15 discharges struck the stern light.

Number 4 copper wire is recommended for protecting a boat. While it is slightly larger than necessary for adequate protection, it is better able to withstand corrosion and vibration and will need little or no subsequent inspection or replacement.



A 3-foot model boat at the Westinghouse High-Voltage Laboratory is struck by 3,000,000 volts of man-made lightning. With no lightning protection (left), currents arc dangerously around the windshield and over the side of the boat. Notice how arcs reach out over the surface of the water. With the mast grounded to a metal plate on the hull of the boat (right), the lightning currents are carried harmlessly into the water

MIT Develops Small Rocket Motor for Testing Fuel Efficiencies

A rocket motor small enough to be held in a person's fist is helping chemical engineers at the Massachusetts Institute of Technology develop fuels for full-size rocket-powered missiles. By running on very small amounts of fuel and by eliminating the need for elaborate safety precautions, it makes possible experiments costing far less than full-scale tests.

The results of experiments with the "microrocket" have already brought about a more complete understanding of rocket fuel combustion. Future work will continue to fill in this picture and is also expected to provide answers to specific rocket design problems.

The MIT microrocket uses only two pounds of fuel in the one minute during which 12 tons would be used in a rocket the size of a German *V-2*. The microrocket operates on exactly the same principle and with the same high efficiency as its larger prototypes—but on a greatly reduced scale.

Although built to use any liquid rocket fuels, the microrocket has to date been used chiefly with a combination of liquids which ignite spontaneously on contact. When they come together inside a rocket motor, the resulting flame makes a tremendous amount of heat and resulting power.

The microrocket builds up more than 300 pounds of pressure inside the motor, shoots gas out of its nozzle at a speed of about 5,000 miles per hour, and produces heat at the same rate as does a furnace big enough to heat an 8-room house.

Jets of the microrocket fuels, shot through 0.01-inch diameter holes, come together inside the chamber which is only 0.5 inch in diameter.

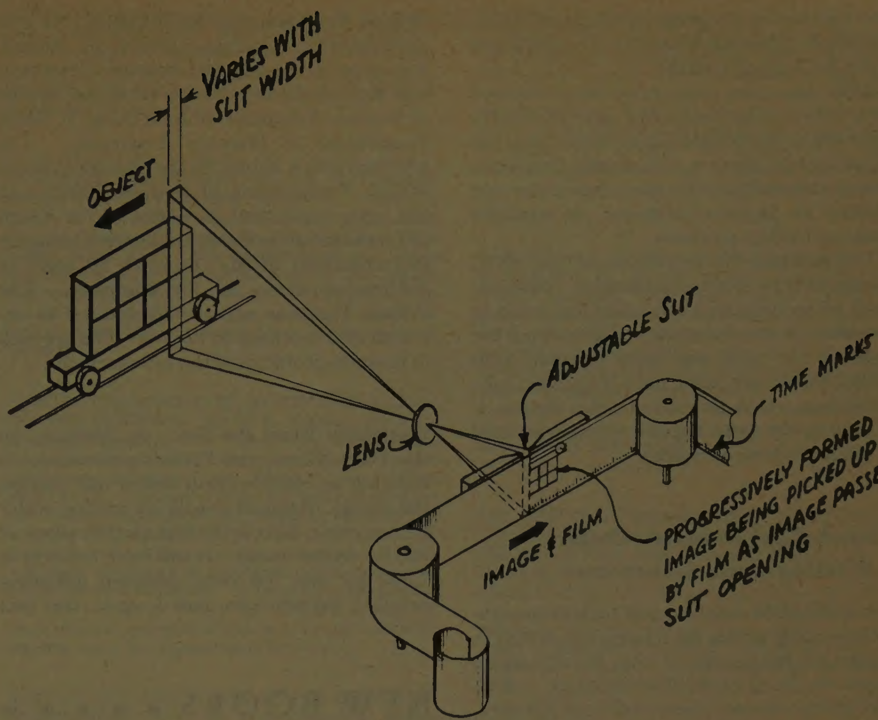
Beckman and Whitley Develop Temporal Sequence Camera

By the use of a camera system developed by Beckman and Whitley, Inc., of San Carlos, Calif., a continuous nonintermittent record may be made of the complete sequence of events taking place in a specified region of space, and during the period that this record is being made, time is also recorded on the film with a precision of one part in 100,000. Thus, all activities taking place within or passing through this region of space are recorded and the simultaneous time required for this activity may be determined. The resulting record is a position-time photograph where the ordinate is position and the abscissa (along the length of the film) is time.

The camera system is able to measure both acceleration and velocity of an object traveling along a track or launcher by either a direct measurement from the optical image or by triggering auxiliary time markers on the film with electric contacts mounted along the launcher. A precision of one-half mile per hour at 1,000 miles per hour is possible. An optical image taken after the object has left the launcher will give velocity and acceleration of the object in space.

Other typical applications are determination of flight time and detonation point of shells or of bombs from aircraft, continuous record of an object striking or entering a surface, recording of linear nonuniform motion such as oscilloscope traces, recording of electric impulses from many types of transducers, and indoor intermittent time and position sequence photographs produced by lighting the subject with stroboscopic lamps during its motion.

Some of the uses typify a unique characteristic of the camera. The camera continuously provides unexposed film that is at all times ready to record an event and, since this process is carried on nonintermittently, the beginning of the event is always recorded. The measurement of the opening and closing time and pattern of an interlens shutter would be a further example of the use of this feature of the camera.



Graphic sketch of the formation of an image by the Beckman and Whitley Temporal Sequence Camera. The object is photographed only during the time it is in the optical plane created in space by the projection of the slit through the camera lens. The object is shown part way through this plane and hence has not appeared in its entirety on the film. The resulting image on the film may bear a close resemblance to the original object or it may assume a variety of distortions depending on the relative velocities of the film and the image

Scientific Institutions Conduct Joint Survey of Cuba's Industry

Sponsorship by the International Bank for Reconstruction and Development of a survey of industrial potentials in the Republic of Cuba has disclosed that three prominent American scientific institutions had voluntarily combined the resources of their staffs and laboratories to provide industrial research in foreign countries on a nonprofit basis. The three institutions are Southwest Research Institute of San Antonio and Houston, Tex., Armour Research Foundation of Chicago, Ill., and Stanford (Calif.) Research Institute—all nonprofit, public service organizations.

The mission will study Cuba's economy, at the request of the Cuban government, in the light of modern scientific, technical, and financial knowledge and will make practical suggestions to the International Bank. The survey will cover segments of Cuba's economy into which investment funds, domestic or foreign, public or private, might be directed; methods of raising agricultural and industrial production; and measures for strengthening Cuba's economic and fiscal organization and practices.

The Cuban survey will include agriculture and animal husbandry, mines, industry, power and other public services, transportation, international commerce, availability and utilization of labor, local capital resources and mechanisms for channeling them into productive investment, foreign trade, and other factors.

Superthin Steel Developed for High-Frequency Electronic Use

Steel so thin it takes ten layers to equal the thickness of a human hair has been developed by the research laboratories of Armco Steel Corporation, Middletown, Ohio. Need for a superthin alloy with special magnetic properties came with the development of high-frequency electronic equipment.

The thin steel alloy is rolled on a tiny mill especially built for the job. Work rolls on this mill are only 5/16 inch in diameter yet they are called upon to support pressures measured in tens of thousands of pounds.

A typical production run starts by cold reducing the alloy on a larger mill to a thickness somewhere between 0.006 and 0.002 inch. The material is then readied for the final reduction by cutting the foot-wide metal into 2-inch strips. After successive passes through the special mill, the alloy has been elongated some 400 times, and reduced in thickness to 0.00025 inch.

In order to test the performance of these magnetic alloys, the strip is slit into ribbons 0.1 inch wide on a jig which uses razor blades as cutters. The ribbons are then coated, wound into tiny coils, and annealed.

A recent order for four test coils of this ribbon weighed so little that 2,250 such orders would yield only one pound of metal. This order was shipped quite securely by first class mail in an aspirin box.

RCA Demonstrates Color TV Transmission Over Coaxial Cable

In an experimental transmission from Washington, D. C., the Radio Corporation of America demonstrated recently that its all-electronic color television system can use standard coaxial cables to carry programs in color from point to point over long distances. RCA simultaneously showed how ultrahigh-frequency radio relays can be employed to extend coverage from terminal stations.

During the demonstration, color signals from a special program originating at the studios of the National Broadcasting Company's television station *WNBW* in Washington were transmitted over more than 200 miles of coaxial cable to NBC's station *WNBT*, New York, N. Y.

The signals were put on the air in both very-high and ultrahigh frequencies. The very-high-frequency images from *WNBT* were picked up on color receiving sets at RCA Laboratories, Princeton, N. J., about 45 miles from New York. The ultrahigh-frequency pictures traveled by radio relay to NBC's experimental station at Bridgeport, Conn., for rebroadcast

All standard black-and-white television sets in the New York metropolitan area that were tuned to *WNBT*'s Channel 4 received

the Washington program in black and white, effectively demonstrating the compatibility of the RCA color system.

RCA has also announced that research work on its color tubes has now reached a point where receivers utilizing these tubes can produce color pictures of increased brightness and of substantially the same resolution and stability as pictures produced on standard black-and-white receivers.

The increase in brightness of the RCA tricolor tubes is due to two factors: development of an improved red phosphor, making it possible to eliminate the red filter from the front of the tube and thus increase light output two to one; and, use of improved tube techniques which provide a higher light output, using the same applied voltages as used in previous demonstrations.

French Coal Industry Orders Westinghouse Generators

A $2,650,000 order for two turbine generators to supply power for mining operations in France has been received from Houillieres du Bassin du Nord et du Pas-de-Calais, a division of the country's national coal industry, it was announced recently by the Westinghouse Electric International Company.

The two 50,000-kw turbine generator units will be installed at the Dechy power station, which is located in the coal fields of the Nord Department. The units will burn waste fuel from surrounding mines. Any energy they produce not needed for mining operations will be fed into the French national power system.

Scheduled for delivery in June and August of 1951, the generators are, essentially, duplicates of two units now operating at the Harnes plant, about six miles away, in the same coal fields. Harnes was the first American-type power station in operation in Western Europe.

Electronic Anemometer Measures Winds 80 Miles Above the Earth

An electronic method for measuring winds 55 to 80 miles above the earth was disclosed recently by scientists at Stanford University. The new method utilizes a radio technique of analyzing the drift of meteor trails to measure wind speeds and directions in the ionosphere at altitudes which are twice as high as can be reached by sounding balloons at the present time.

The research at Stanford University, financed by the Office of Naval Research, is expected to give useful applications in the design of long-range guided missiles and in weather forecasting. The new method is based on the fact that the electric disturbances caused by the heat of a meteor's passage are efficient reflectors of radio waves and may be detected by a radar-like technique.

Each disturbance lasts only a second or two but, during that time, drifts like a smoke puff under the influence of outer atmosphere winds. By using an electronic anemometer to determine the rate of drift and the direction of each disturbance, and then averaging many measurements, the scientists are able to determine the average motion of the air mass between 55 and 80 miles high.

Wilson Professorship Established. A new professorship honoring Charles E. Wilson, president of the General Electric Company, has been established at the Graduate School of Business Administration—George F. Baker Foundation of Harvard University. The professorship is known as the Charles Edward Wilson Professorship of Business Policy and has been established by action of the Board of Directors of the General Electric Company in recognition of Mr. Wilson's 50 years of continuous service to the company. The Wilson Professor will devote himself to research and teaching in the over-all approach to business problems of top management.

Electricity From the Sea. At Abidjan, on the Ivory Coast, the French government is building an electric plant which will harness the energy obtained simply by mixing water with water. This is the first electric plant of its kind in the world. It will have a power of 7,000 kw and has been designed following detailed experiments based upon the fact that temperatures in the surface waters of the oceans reach 82 degrees Fahrenheit in tropical countries and cold waters from the depths are usually 46 degrees Fahrenheit. By bringing these together, huge quantities of energy may be obtained. The process consists of evaporating under vacuum part of the warm surface waters. The resulting steam is "inhaled" by the condenser, which is cooled by the deep waters, and on the way it passes through a turbine driving an electric generator.

Basic Instrumentation Office at NBS. Basic instrumentation research at the National Bureau of Standards is now being co-ordinated by the Bureau's new Office of Basic Instrumentation. The office co-ordinates a program of evaluation and improvement of instruments for measuring basic physical quantities. The concept of the office was developed jointly by the National Bureau of Standards, the Office of Naval Research, the Office of Air Research, and the Atomic Energy Commission.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

(The) ACCELERATION OF PARTICLES TO HIGH ENERGIES. Institute of Physics Convention, Electronics Group, May 1949. (Physics in Industry Series.) Institute of Physics, London, 1950. 58 pages, illustrations, diagrams, tables, 10 by 6¼ inches, linen, 10s.6d.; $1.60 United States, including postage and packing. Based on papers presented on the last day of the 1949 Convention of the Institute of Physics, this book covers various cyclic and linear accelerators of particles. The principles, design, and performance of cyclotrons, betatrons, synchrotrons, electrostatic generators, and linear accelerators are discussed. A selected bibliography is placed at the end of each chapter.

BRITISH ELECTRICAL POWER CONVENTION. First, held at Torquay, June 13 to 17, 1949. *Proceedings*, British Electrical Power Convention, 16 Stratford Place, London, W. 1, England, 1950. 334 pages, illustrations, diagrams, charts, maps, tables, 8¾ by 5½ inches, linen, 10s.6d. This volume contains five papers dealing with consumer service, high-voltage transmission in Great Britain, switchgear, and power transformers for 200 kv and above systems, high-voltage research and development as they pertain to cables, and the electrical contractor's place in the industry. Lists of the delegates, visitors, and members are included.

ELECTRIC POWER SYSTEM CONTROL. (Monographs on Electrical Engineering, Volume XI.) By H. P. Young. Third edition revised and enlarged. Chapman and Hall, Ltd., London, England, 1950. 456 pages, illustrations, diagrams, charts, tables, 8½ by 5½ inches, cloth, 28s. Beginning with the parallel operation of generators, this monograph continues with discussion of voltage control and the automatic synchronizing of A-C generators. The control of power reactance is explained. Considerable space is devoted to circuit breakers, switchgear arrangements, and short-circuit calculations. Power station interconnection is covered, and the general principles of automatic supervisory control are fully stated. In two new chapters the principles of protective gear circuit design are applied to the protection of feeders, and to machines, transformers, and busbars.

ELECTRICAL ENGINEERING ECONOMICS, a Study of the Economic Use and Supply of Electricity Volume I. By D. J. Bolton. Third edition. Chapman and Hall, London, England, 1950. 292 pages, diagrams, charts, tables, 8¾ by 5½ inches, cloth, 25s. This book provides practicing engineers and students with a plain account of such elementary economics as most nearly concerns them, together with its application to certain engineering problems. Volume 1 of the 2-volume set contains Part 1, which deals with general principles and restates the classical treatment of productivity, and Part 2, which covers the general problem of economic choice of electrical plant. Part 3, on costs and tariffs in electricity supply, will be issued as Volume 2 of the set.

ENGINEERING PRECISION MEASUREMENTS. By A. W. Judge. Second edition revised. Chapman and Hall Ltd., London, W. C. 2, England, 1950. 363 pages, illustrations, diagrams, charts, tables, 9¾ by 5½ inches, cloth, 30s. Provides a general survey of the more important methods of precision measurements employed in the engineering workshops, and describes in detail some of the more widely used ones from the viewpoint of the user in the gauge room, inspection department, toolroom, and machine shop. For some cases, the principles of the methods upon which the instrument is based are given, and typical examples are described. An abridged account is also included.

ENGINEERS OF THE SOUTHWEST PACIFIC, 1941–1945. Volume 3, ENGINEER INTELLIGENCE. By the Office of the Chief Engineer, General Headquarters, Army Forces, Pacific. Reports of Operations United States Army Forces in the Far East, Southwest Pacific Area, Army Forces, Pacific, 1948. 467 pages, illustrations, charts, maps, tables, 11¾ by 9 inches, cloth, $7, for sale by the Superintendent of Documents, Government Printing Office, Washington 25, D. C. This detailed summary of activities is arranged chronologically and discusses primarily mapping operations, research, and reports within the several years in question. Considerable detail is presented on the course of development, the changing concept, organization, achievements, and obstacles encountered. The volume is profusely illustrated by a variety of descriptive or explanatory maps and charts, and a large number of directives, reports, and other declassified original documents are reprinted in appendixes.

GEOCHEMISTRY. By K. Rankama and T. G. Sahama. University of Chicago Press, Chicago, Ill., 1950. 912 pages, diagrams, charts, tables, 9¾ by 6¾ inches, linen, $15. Part 1 of this comprehensive treatise deals with the general laws and regularities which determine the abundance and manner of occurrence of each particular element. Part 2 deals with the individual geochemical features of each of the elements in the Periodic System, as well as with the empirically established causes of the manner of occurrence of the various elements. Quantitative aspects are emphasized throughout. Tables of specialized data are appended, a bibliography of some 700 items is included, and a detailed 60-page subject index is provided.

(An) INTRODUCTION TO THE THEORY AND DESIGN OF ELECTRIC WAVE FILTERS. By F. Scowen, with a foreword by Sir A. J. Gill. Second

edition revised, Chapman & Hall Ltd., London, England, 1950. 188 pages, diagrams, charts, tables, 9 by 5 1/2 inches, linen, 18s. Provides the basic principles of filter theory and a simple method of design using templates, nomographs, and charts. The theory of the ladder-type filter is described in detail, as is a method for its design. The theory of the lattice-type filter is dealt with in a brief manner, as are the developments due to Cauer and the design of crystal filters. Darlington's insertion-loss method of filter design is fully treated. A bibliography is also included.

KENT'S MECHANICAL ENGINEERS' HANDBOOK. (Wiley Engineering Handbook Series.) Volume 1. Design and Production Volume, edited by C. Carmichael. Volume 2. Power Volume, edited by J. K. Salisbury. John Wiley and Sons, New York, N. Y.; Chapman & Hall, London, England, 12th edition paged in sections, 1950. Illustrations, diagrams, charts, tables, 8 1/2 by 5 1/2 inches, leather, $8.50 per volume. Volume 1 now primarily directed toward the engineers who design and manufacture machinery, appliances, mechanical equipment, and other engineered products, this edition provides a summary of the essentials of the field together with pertinent data. The six main sections cover selection of materials, design principles, design and selection of machine components, production processes, production plant equipment, and mathematical tables. References are included in the text and at the ends of many of the chapters.

Volume 2, thoroughly revised and rewritten, covers the entire field of heat-power engineering and transportation as well as the important aspects of fluid flow. The first four sections treat power processes. The service functions, pumping, and piping, are dealt with in the next two sections. Power-producing equipment, refrigeration, heating, ventilating, air conditioning, transportation, and electric power are then discussed. The remaining sections are devoted to atomic energy, instrumentation, power test codes, and mathematical tables.

PRINCIPLES OF ELECTRIC AND MAGNETIC CIRCUITS. By W. B. Boast. Harper and Brothers, New York, N. Y., 1950. 367 pages, illustrations, diagrams, charts, tables, 9 1/2 by 6 1/4 inches, linen, $4.25. This text is designed for use in an introductory course in electrical engineering. Parts 1 and 2 cover basic concepts of simple electric and magnetic circuits; Part 3 deals with electromagnetic induction; Part 4 presents methods of electric network analysis; and Part 5 treats important supplementary aspects: conduction circuits with irregular boundaries, capacitance as a circuit element, and systematic methods of writing equations for circuits containing resistance, inductance, and capacitance. The rationalized MKS system of units is used, although the English units of magnetic potential gradient and flux density are also emphasized. More than 300 problems are provided.

(The) RADIO MANUAL. By G. E. Sterling and R. B. Monroe. Fourth edition. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England; 1950. 890 pages, illustrations, diagrams, charts, tables, 10 1/4 by 7 3/4 inches, fabrikoid, $12. This comprehensive manual is designed as a text for those engaged in or preparing for the profession of electronics and telecommunications. It begins with a discussion of elementary electrical and radio theory and then considers such topics as both amplitude modulation and frequency modulation broadcasting, radio navigational aids, television, radio-wave propagation, antennas, and radio equipment for emergency services. The three final chapters cover State, Federal and International laws under which radio and television operate.

RAPID TRAVERSE TABLES. By L. J. Goldsmith. Wm. C. Brown Company, Dubuque, Iowa, 1950. 540 pages, diagrams, tables, 8 1/2 by 5 1/2 inches, stiff paper, $5. The products of the natural sines and cosines of angles multiplied by the numbers from one to nine are tabulated for each minute of angle from 0 degree 01 minute to 89 degrees 59 minutes. The values listed are accurate to five figures following the decimal point. The tables are particularly applicable to problems in which the hypotenuse and an adjacent angle of a right triangle are known, such as are found in trigonometry, applied mechanics, and surveying. A special rapid calculator devised for use with the tables is included.

SEMI-CONDUCTEURS ÉLECTRONIQUES ET COMPLEXES DÉRIVÉS, Théories—Applications. By S. Teszner, preface by L. de Broglie. Gauthier-Villars, 55 Quai des Grands-Augustins, Paris, France, 1950. 96 pages, illustrations, diagrams, charts, tables, 11 1/2 by 8 1/4 inches, paper, 1,000 frs. Part 1 of this study gives a general survey of the electronic theory of semiconductivity, and analyzes and interprets the various phenomena connected with or exhibited by the materials having this property. Part 2 discusses applications in the form of oxide rectifiers, crystal detectors, and similarly derived equipment, as well as devices based on the properties of nonlinear resistance and the variation of resistance with temperature.

SYMPOSIUM ON EFFECTS OF LOW TEMPERATURES ON THE PROPERTIES OF MATERIALS (Special Technical Publication Number 78). American Society for Testing Materials, Philadelphia 3, Pa., 1950. 62 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $1.50. This symposium of four papers and discussions brings together some of the existing knowledge of the low-temperature use of plastics, elastomers such as rubber, nonferrous metals, and metal welds. Suggestions for future work in this field are outlined.

ELECTRICAL MACHINES, DIRECT AND ALTERNATING CURRENT. By C. S. Siskind. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 521 pages, illustrations, diagrams, charts, tables, 9 1/4 by 6 inches, cloth, $4.75. Intended as a text for technical institutes and for electrical engineering courses for nonelectricals in engineering colleges, this book discusses in detail all types of modern electric power equipment. It deals with such equipment as generators, transformers, converters, and control devices. A knowledge of elementary d-c and a-c circuit theory and practice is assumed. Mathematical treatment is limited to simple arithmetic, algebra, and a few trigonometric functions.

ESTIMATING AND PLANNING FOR ENGINEERING PRODUCTION. By P. S. Houghton. Blackie and Sons, Ltd., London, England, and Glasgow, Scotland, 1950. 366 pages, diagrams, charts, tables, 9 by 6 inches, linen, 25s. All aspects of production planning are covered, from the estimating of material requirements to the matter of pricing and sales. The bulk of the book, however, is devoted to the processing of metals by machining. Some 200 tables are given to assist production personnel to plan each machining operation so that full use is made of both tool and machine. Examples are given to illustrate the use of these tables.

HEAT AND TEMPERATURE MEASUREMENT. By R. L. Weber. Prentice-Hall, Inc., New York, N. Y., 1950. 422 pages, illustrations, diagrams, charts, tables, 8 1/2 by 5 3/4 inches, cloth, $5. ($6.65 text edition). Describes measurement methods and includes the theoretical principles necessary for their appreciation, intelligent use, and extension. Emphasis is on experimental methods rather than on thermodynamic theory. Part 1 presents the physical principles. Part 2 outlines the procedures for 29 laboratory experiments and includes brief discussions of the theory and photographs of typical arrangements of apparatus. The appendix contains data tables.

HYDROLOGY, THE FUNDAMENTAL BASIS OF HYDRAULIC ENGINEERING. By D. W. Mead. Second edition revised and enlarged by Mead and Hunt, Inc., McGraw-Hill Book Company, New York, N. Y., and London, England, 1950. 728 pages, illustrations, diagrams, charts, maps, tables, 9 1/4 by 6 1/4 inches, cloth, $7.50. Completely revised since its first publication in 1919, this standard text now also provides sections covering recent developments, such as: a discussion of the Bergeron analysis of meterological phenomena in terms of air masses, a new approach to evaporation theory and methods of measurement, the new techniques and possible consequences of producing artificial rainfall, methods of weighing precipitation records, the application of the theory of probability to hydrologic data, and the application of statistical theory to flood frequency.

INTRODUCTION TO EXPERIMENTAL STRESS ANALYSIS. By G. H. Lee. John Wiley and Sons, Inc., New York, N. Y.; Chapman & Hall, Ltd., London, England, 1950. 318 pages, illustrations, diagrams, charts, tables, 9 1/4 by 6 inches, cloth, $5.50. Theory, instrumentation, and basic techniques are covered for the most commonly-used methods: mechanical and electric strain gauges, with particular attention to the resistance wire strain gauge; the photoelastic method; brittle-lacquer techniques; the membrane and electrical analogies; the Beggs deformeter and other miscellaneous methods. The final chapter deals with the evaluation of experimental errors and the transmission of these errors through computational operations.

DYNAMIC GÉNÉRALE DES VIBRATIONS. By Y. Rocard. Second edition revised and enlarged. Masson & Cie, Éditeurs, Paris, VI°, France, 1949. 439 pages, diagrams, charts, tables, 9 by 6 1/4 inches, paper, 1,900 frs. This comprehensive work deals with the dynamics of vibrating systems. Part 1, comprising the first three-quarters of the book, covers mechanical and electric systems: simple pendulums; damping; electromechanical analogies; impedance problems; shock effects; spring systems; bandpass filters; auto-oscillation conditions; and so forth. Part 2 covers basic aspects of acoustical systems: wave propagation under various conditions; loud-speakers; microphone setup; and so forth.

NORMUNGSZAHLEN. (WISSENSCHAFTLICHE NORMUNG 2). By O. Kienzle. Springer-Verlag, Berlin, Göttingen, Heidelberg, Germany, 1950. 339 pages, diagrams, charts, tables, 8 by 5 1/2 inches, bound, 25.50 D.M.; paper, 22.50 D.M. Contains both the theoretical and practical aspects of standard numbers. In the first part the mathematical relationship of numbers and systems of numbers is considered. The second part is devoted to applications, such as measurements, productivity, weights, and in the field of machinery construction. A bibliography and a list of related German standards are also included.

UN NOUVEAU MANOGRAPHE PHOTO-ÉLECTRIQUE (Publications Scientifiques et Techniques du Ministère de l'Air, Notes Techniques Number 32). By P. Barret, Au. Service de Documentation et d'Information Technique de l'Aèronautique, 2 Rue de la Porte-d'Issy, Paris (15°), France, 1950. 14 pages, illustrations, diagrams, 10 1/2 by 7 inches, paper, 180 frs. A manograph or indicator is described in which the action of a diaphragm, responding to the engine-cylinder pressure, controls the width of a slit, which in turn modulates a beam of light. These modulations are registered by an electronic system comprising a photoelectric cell and an oscillograph. Emphasis is on the variable-slit feature which largely eliminates parasitic vibrations.

POCKET ENCYCLOPEDIA OF ATOMIC ENERGY. Edited by F. Gaynor. Philosophical Library, 15 East 40th Street, New York, N. Y., 1950. 204 pages, diagrams, charts, tables, 8 3/4 by 5 1/2 inches, linen, $7.50. This book presents a comprehensive collection of brief explanations and definitions of concepts and terms in the field of nuclear physics and atomic energy. In addition, brief biographical sketches of outstanding workers in the field are included as well as descriptions of important nuclear research laboratories, power plants, and installations. German equivalents are given for a great many of the terms defined.

PRIMARY BATTERIES. By G. W. Vinal. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1950. 336 pages, illustrations, diagrams, charts, tables, 8 1/2 by 5 1/2 inches, cloth, $5. This comprehensive work covers the history, theory, materials, chemical reactions, manufacture, and operating characteristics of primary batteries. New types of special-purpose batteries are covered, such as for low-temperature conditions, large current production, and so forth. Practical material is presented on silver oxide and chloride batteries, mercury oxide batteries, and perchloric and fluoboric acid batteries. There is a separate chapter on standard cells.

PRINCIPLES OF ENGINEERING ECONOMY. By E. L. Grant. Third edition. Ronald Press Company, New York, N. Y., 1950. 623 pages, charts, tables, 9 1/4 by 6 inches, cloth, $5. Useful as a reference for the practicing engineer and the industrial manager as well as a text for engineering students, this book discusses the principles which govern the economic aspects of an engineering decision. Among the new material in this edition are a consideration of prospective price changes, discussion of the relation of income taxes to economy

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

studies, and a new treatment of the theoretical aspects of replacement economy. More than two-thirds of the book has been rewritten, and most of the 400 problems are new.

PROPERTIES OF METALS AT ELEVATED TEMPERATURES. By G. V. Smith. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada, London, England, 1950. 401 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $7. This book collects and correlates the results of 25 years of research work on the effect of temperature on the properties of metals. The initial chapters deal with the nature of plastic deformation and fracture of metals from a metallurgical viewpoint. Next, the test apparatus and test procedures employed in evaluating metals for service at elevated temperatures are described. The effects of such variables as chemical composition, manufacturing practice, and heat treatment are then discussed. The questions of sealing and changes in microstructure are also considered. A final chapter deals with the problem of design for service at elevated temperatures. Numerous illustrations, an appendix with useful data, and an extensive bibliography are also included.

RECOMMENDED PRACTICES FOR RESISTANCE WELDING. C1.1-50. American Welding Society, 33 West 39th Street, New York, N. Y., 1950. 60 pages, diagrams, charts, tables, 9 by 6 inches, paper, $1. This new edition represents a modification and expansion of the Standard originally issued in tentative form in 1946. It includes welding schedules for spot and seam welding of mild and medium-carbon steels, low-alloy steels, stainless steels, nickel, Monel, Inconel, and magnesium alloys. Recommended practices for projection welding cover low-carbon and stainless steels. Flash welding data are provided for low and medium forging strength steels. A section on methods of testing resistance welds is also included.

REPORT ON THE STRENGTH OF WROUGHT STEELS AT ELEVATED TEMPERATURES. (Special Technical Publications Number 100). Prepared by R. F. Miller and J. J. Heger. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1950. 109 pages, charts, 11 by $8^1/_2$ inches, paper, $3. This report is a graphical presentation of published information on the subject. Tensile, creep, and rupture properties of the standard commercial grades are shown together with the sources from which they were obtained. The first section covers plain carbon and alloy steels containing molybdenum and up to 3-per cent chromium; the second deals with the ferritic and austenitic steels containing more than 5-per cent chromium. Applicable ASTM standards are included.

STEAM TURBINES AND THEIR CYCLES. By J. K. Salisbury. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 645 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, linen, $9. Of particular interest to those concerned with the application of steam turbines in power plants, this book provides a detailed treatment of the following topics: basic thermodynamics and the fundamentals of steam turbine design; the regenerative cycle and the calculation of heat balances; cycle evaluation methods, including the simple and accurate calculation of losses in the feedwater-heating cycle; data and methods for determining steam rates and heat rates of steam turbines of any size. The appendix includes many useful tables, and a selected list of references.

TELEVISION SIMPLIFIED. By M. S. Kiver, Third Edition. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England; 1950. 608 pages, illustrations, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $6.50. This book explains the basic principles of television and their most recent applications. Following the pattern set in the two previous editions, chapter 1 presents an outline of the various units that combine to make a television system. Each succeeding chapter discusses in detail a different section of the television receiver. One chapter is devoted to an explanation of frequency modulation, and a new chapter discusses the principles of the recently devised intercarrier Sound Television System. The color television chapter has been brought up to date and covers the new CBS, RCA, and CPI systems.

THRESHOLD SIGNALS. (Massachusetts Institute of Technology, Radiation Laboratory Series, volume 24). Edited by J. L. Lawson and G. E. Uhlenbeck. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 388 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5. This book provides both a theoretical and experimental analysis of the factors which affect the perception of desired signals in the presence of various kinds of interference. Although emphasis is placed on signals and interference which are usually encountered in pulsed systems, other systems, such as continuous-wave ones modulated either in frequency or amplitude, are briefly discussed. In addition to signals which consist of trains of pulses, a treatment is given of pulse trains which are amplitude-modulated in some desired way.

UNIVERSITIES OF THE WORLD OUTSIDE USA. Edited by M. M. Chambers. First edition, 1950. American Council on Education, Washington, D. C. 924 pages, $9^3/_4$ by $6^1/_2$ inches, cloth, $12. Succinct discussions are given of the organization and operation of both large universities and small schools including statistics of the teaching staffs, the fee systems, and the annual incomes and expenditures with indications of the sources of financial support. More than 2,000 institutions of higher education in some 80 countries and localities outside of the United States are covered. A general survey of the educational conditions in each country is included, as well as a discussion of the international exchange of students and teachers.

HOCHSPANNUNG UND HOCHLEISTUNG. By J. Biermanns. Carl Hanser Verlag, Munich, Germany, 1949. 655 pages, illustrations, diagrams, charts, tables, $9^3/_4$ by $6^3/_4$ inches, cloth, 52 DM; unbound, 49 DM. This comprehensive and detailed work on high-voltage technique begins with the elements of the electrostatic field, the nature of dielectrics, and insulation problems. The succeeding two chapters deal with the problems of overvoltages and short circuits, together with protective measures and devices. Switchgear, capacitors, and other equipment are dealt with. There is a brief discussion of energy transmission by means of high-voltage direct current.

HOCHSPANNUNGSTECHNIK. By A. Roth and A. Imhof. Third edition. Springer-Verlag, Vienna, Austria, 1950. 704 pages, illustrations, diagrams, charts, tables, 10 by 7 inches, paper, $15; bound, $16. This discussion of high-voltage technique begins with the properties of electric fields and a comprehensive survey of the dielectric characteristics of insulating materials and the effective use of these materials. A high-voltage testing room is described, and separate chapters are devoted to high-voltage setups for alternating and direct current. In this revised edition, the section on high-current problems in high-voltage practice has been rewritten, and material is now included on the basic principles of apparatus for X-ray and atomic physics investigations and other recent developments.

INDUSTRIAL ELECTROCHEMISTRY. By C. L. Mantell. Third edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 781 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $8.50. Points out and emphasizes the technological importance of electrochemical processes, stresses their practical aspects, and adheres to the engineering viewpoint. It covers theory, the various types of processes, their applications and products, and equipment and methods in each. A large amount of technical and operating data gathered in the field are included. Extensive revisions and additions are made in this edition to bring the material up to date and to take account of the tremendous expansion in the electrochemical and process industries.

INDUSTRIAL INSPECTION METHODS. By L. C. Michelon. Revised edition. Harper and Brothers, New York, N. Y., 1950. 566 pages, illustrations, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, cloth, $6. Reflecting the growth in techniques, standardization, new devices, and statistical methods developed during the war, this book considers precision measurement as it is today. It provides a comprehensive and scientific presentation of the principles and current practices in industrial inspection work. As in the first edition, there are liberal use of illustrations, emphasis on standard terminology, and step-by-step presentation of good inspection practice. Statistical methods of quality control are covered.

INSPECTION ORGANIZATION AND METHODS. By J. E. Thompson. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 369 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, linen, $5. Written from the management viewpoint, this book provides tested methods for improving efficiency, simplifying procedures, and reducing costs in inspection departments. Complete data necessary for the orderly planning, accomplishment, and recording of inspection examination an testing are supplied. Modern equipment and processes are discussed, including the various methods of nondestructive testing. The appendixes contain typical inspection job evaluations and inspection specifications.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Liquid Metals Handbook. Published under the joint sponsorship of the Atomic Energy Commission, the Office of Naval Research, and the Navy Bureau of Ships. Gives information on metals having low melting points so that they become liquid at room temperature or within a few hundred degrees of room temperature. 194 pages. Available upon request from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at the price of $1.25 each.

Statistics Can Change a Job Classification. Discusses consumer attitude on quality, organizing a successful department, applying the statistical approach, specifications, raw material, gauges and gauging methods, actual floor production, final inspection, and customer complaints. Four pages. Illustrated with charts, graphs, and tables. Copies are available at ten cents each from V. W. Palen, Bureau of Public Information, New York University College of Engineering, New York 53, N. Y.

Equipment—1949—Électricité de France. Gives a general idea of the work accomplished by Électricité de France, a merger of all the French power companies, during the year 1949. Further information concerning the pamphlet may be obtained upon request from the French Office of Power Stations, at 1322 18th Street, N. W., Washington 6, D. C.

Refrigerant Tables, Charts, and Characteristics. Contains a complete compilation of refrigerant properties in chart and table form including tables of properties, pressure-enthalpy diagrams, and Mollier charts for all commonly used refrigerants. 93 pages. Copies may be obtained from the American Society of Refrigerating Engineers, 40 West 40th Street, New York 18, N. Y., at $1.50 per copy, bound in paper, and $2 per copy, bound in cloth.

High Power Pulse Transformer Design and Development. Deals with the theory of pulse transformers, including their operation and materials of construction. Also describes in detail the Armour Research Foundation interleaved winding design and its considerations. 229 pages including diagrams, graphs, and tables. Available at $8 in microfilm and $28.75 in photostat from the Library of Congress, Photoduplication Service, Publication Board Project, Washington 25, D. C.

Colorimetry. Describes the standards and measurement methods developed by the National Bureau of Standards in the field of colorimetry, giving the basis for each technique and showing how one method supplements the other. 56 pages. Illustrated. This pamphlet is available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 30 cents a copy.